5th VERSION
17 January 2018

What is an astrolabe, & what is an astrolabe not

David A. King @ Frankfurt

@ Johann Wolfgang Goethe University, Frankfurt,
em: king@em.uni-frankfurt.de, publications downloadable at davidaking.academia.edu

"Ptolemy was riding on a donkey with an armillary sphere in his hand; it fell and the donkey trod on it and squashed it: the result was an astrolabe." *

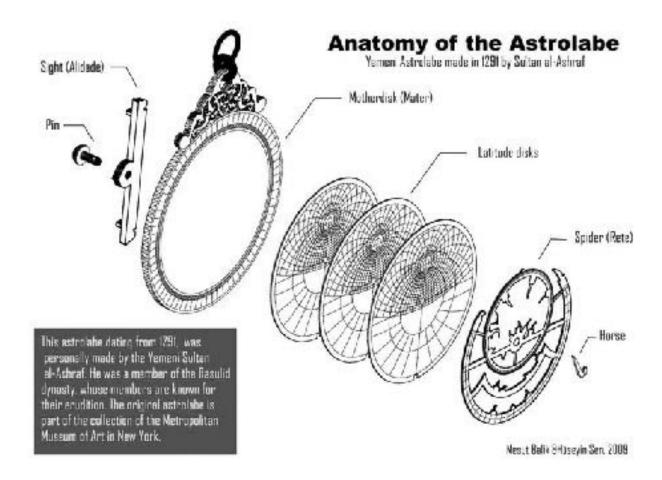
"The astrolabe is an instrument with which one can achieve the solution of many astronomical problems, for practical and didactic purposes, not including those relating to the (moon and) five planets, by the easiest procedures and simplest methods." **

"Perception is more important than reality. If someone perceives something to be true, it is more important than if it is in fact true. This doesn't mean you should be duplicitous or deceitful, but don't go out of your way to correct a false assumption if it plays to your advantage." ***

"Astrolabes are inclinometers that were used for navigation and locating astronomical objects from ancient times to the Renaissance." ****

* Legend recorded in a 13th-century Arabic text (see King, *Synchrony*, XIIIe: 595).
** The Andalusî astronomer Abu l-Salt, ca. 1000, in his treatise on the use of the astrolabe (see *Synchrony*, XIIIe: 603).
*** Ivanka Trump, *The Trump Card* (2009), cited at http://www.amreading.com/2017/04/25/the-7-most-singularly-terrifying-quotes-from-ivanka-trumps-trump-card-book/.
**** Anonymous, article "Inclinometer" in *Wikipedia*.

**5th VERSION
17 January 2018**

Note to reader: This document was prepared with PAGES software on a MacMini. There are many unwanted spaces between items in the bibliography. Because the software has such a absurd name – PAGES – I have not been able to get advice from users' groups on the internet. Any help that any readers of this text – if there ever are any – can provide will be gratefully appreciated. (In the old days, I had similar problems with texts prepared with WORD, and the books that were being prepared with those texts were published with the problematic features in place.)

A breakdown of a typical astrolabe showing the basic components. This diagram was inspired by the astrolabe made in 1291 by the Yemeni Sultan al-Ashraf, who was a prolific astronomer and instrument-maker. Notice the plates look very different from European plates, because they all serve latitudes in the Yemen and the Hejaz. A standard, very early, Greek, Islamic or European astrolabe might have seven sets of markings for the seven climates of Antiquity, six on three plates and one on the mater. [Reproduced with kind permission of Mesut Balik and Hüseyin Sen.]

A foretaste of things to come.

5th VERSION
17 January 2018

Table of contents:

5th VERSION
17 January 2018

5th VERSION
17 January 2018

Do we need another article about the astrolabe? [1]

Introduction

Imagine all you see of the heavens as being situated on a sphere of arbitrary radius. We call this imaginary sphere the celestial sphere. On it are the fixed stars and the ecliptic or apparent annual path of the sun against the background of the fixed stars between the limits of the circles of Cancer and Capricorn. (A celestial globe is an instrument displaying stars and these principal circles. An armillary sphere is an instrument featuring all of these circles, and more, as rings.) The celestial sphere appears to rotate about a celestial axis pointing toward a celestial pole, the motion being parallel to a celestial equator. The altitude of the celestial pole above the northern horizon is a measure of the latitude of the locality. The position of any celestial object relative to the horizon of the observer at the centre of the sphere can be defined by its altitude above or below the horizon and its direction or azimuth around the horizon. The moon and planets need not concern us here because they "wander" about the ecliptic and their motions are too unwieldy for our present purpose. So far, so good. Some people knew this 2,000 years ago. Kids should learn this at school, but they usually don't. I certainly didn't.

These spherical concepts and instruments can all be simplified and represented in a plane. This is achieved by means of a stereographic projection, the three-dimensional celestial sphere being reduced into the plane of the celestial equator, parallel to which all celestial motion appears to rotate. The projection has two very useful properties: circles on the sphere project into circles on the plane, and angles on the sphere project into equal angles on plane. Brilliant!

The resulting astrolabe becomes a model of the universe that you can hold in your hands. It is a two-dimensional representation of the three-dimensional celestial sphere, with all of the principal stars and the most important celestial circles. The astrolabe can be set to represent the appearance of the heavens above and below the observer's horizon at any

---

[1] On medieval instruments in general, including European ones, see King, "Astronomical instruments between East and West" (Vienna, 1994). The present article was written independently of my 2005 study "The neglected astrolabe – A supplement to the standard literature on the favourite astronomical instrument of the Middle Ages", dealing with medieval Islamic and European astrolabes, which has full references and a more detailed bibliography.

locality and at any time. The celestial part can rotate over the terrestrial part and simulate the apparent daily rotation of the heavens. And that is why it's really brilliant and extremely useful.

WHAT IS AN ASTROLABE?

James Evans' first paragraph on the astrolabe in his *The History and Practice of Ancient Astronomy*, p. 141, almost says it all (with my additions in italics):

> "The astrolabe is a working model of the heavens, a kind of analog(ue) computer. In the astrolabe, the celestial sphere has been projected onto a plane surface, *actually the celestial equator*. Thus, the astrolabe can be considered a two-dimensional version of a celestial globe or armillary sphere. The basic principle of the astrolabe was a discovery of the ancient Greeks, but the oldest surviving astrolabes are medieval. Throughout the Middle Ages, first in Islam and later in Christian Europe, the astrolabe was the most common astronomical instrument. When precise results were called for, the astronomer had recourse to specialized instruments *and to extensive tables for timekeeping (Islam only)* and to tedious trigonometric computation. The beauty of the astrolabe was that approximate solutions (good to the nearest degree or so) to astronomical problems could be found by a mere glance at the instrument."

Comments: It should be mentioned that the astrolabe enables one to represent the heavens with respect to the sky of an observer. Also, the solutions one can obtain with an astrolabe are approximate only in the sense that the size of the instrument is limited. Theoretically, the solutions are exact, because the astrolabe is based on exact mathematical procedures.

The celestial part, called the rete, is a circular frame fitted with pointers for a selection of bright stars and an excentric ring for the ecliptic. The terrestrial part, called the plates, consists of a series of projections for different latitudes, and displays the meridian and the horizon and altitude circles from the horizon (0°) up to the zenith (90°). The rete lies on top of the plates which are fixed inside the mater, the front sometimes devoid of markings bounded by a raised 360°-scale. The back of the earliest astrolabes (Greek/Islamic/Latin) was devoid of markings beyond an altitude scale. The sighting device attached at the centre of the back is called the alidade and its movable extremity can move over the altitude

scale to measure celestial altitudes. The ensemble is held together by a pin at the back fitted with a wedge at the front. Once the altitude of the sun or any star has been measured on the back of the instrument, this information is entered on the front of the instrument. One simply moves the appropriate position of the sun on the ecliptic ring or the appropriate star-pointer so that it lies on the appropriate altitude circle on the plate suitable for one's locality. Then indeed one has a model of the celestial configuration at that location at that time.

The astrolabe also displays the instantaneous configuration of the ecliptic relative to the horizon – the points of intersection are called the horoscopus or ascendant and the descendant – and to the meridian – the intersections are called upper and lower midheaven. The twelve astrological houses based on these these major cusps and the presence of the sun, moon and planets in the individual houses and their imaginary influences on each other constitute the essentials of a horoscope or prediction. The astrolabe can at least show the configuration of the ecliptic. (A mechanical device for computing solar, lunar and planetary positions, called an equatorium, is vary rarely found on the backs of European astrolabes; otherwise these positions could be taken from an annual ephemeris, such as was available in Greek, Islamic and Latin astronomy.)

The astrolabe was invented in the Hellenistic world, perhaps by Theon of Alexandria in the 4th century CE, although the underlying theory was known already to Hipparchus of Rhodes in the 2nd century BCE. The theory of stereographic projection need not concern us here, being so well documented in the modern astrolabe literature. Several Greek texts survive expounding the use of the instrument have survived, but only one astrolabe with Greek inscriptions survives, a Byzantine piece made in Constantinople in 1062. (Some confusion has arisen in the modern literature as a result of the fact that the great Ptolemy of Alexandria in the early 2nd century CE called his armillary sphere by the same term as the later instrument that concerns us here.)

Muslims encountered the astrolabe in the 8th century in Harran, on the borders of the Byzantine Empire and the new Muslim domains. It became the favourite instrument of the Muslim astronomers of the Middle Ages, from Baghdad to Muslim Spain, to the Yemen, to Central Asia and India. Several hundred Islamic astrolabes survive in museums around the world, though most are from the last few centuries. It is the early ones that are usually more interesting from a historical and scientific point of view. And

some astrolabes early and late are veritable scientific works of art. In addition to the numerous late examples, mainly from the Maghrib, Iran and India, we now have over a century's worth of fakes with inscriptions intended to deceive. (Astrolabes were not the only instruments inherited by the Muslims from their Greek predecessors: celestial globes, armillary spheres, fixed observational quadrants, and different varieties of sundials also became popular, although portable quadrants are mainly Muslim inventions.)

Christian Europeans, eager for the scientific knowledge of their Muslim neighbours, encountered the astrolabe in the Iberian Peninsula in the 10th century. Arabic texts were translated, Islamic instruments were copied, or so we used to think. The earliest astrolabe with Latin inscriptions dates from 10th-century Catalonia, and bears no resemblance to any known Western Islamic pieces or any later Spanish pieces; rather, it seems to be the sole surviving evidence of a Roman tradition. (We shall introduce what may be the second oldest European astrolabe below.) The other earliest medieval Spanish astrolabes also bear little resemblance to earlier Andalusî pieces. Nevertheless they represent the earliest one out of several medieval European regional schools, later ones being the English school, based in London and Oxford; the French school, based in Paris; the German school, based in Vienna; and the Italian school, as yet not properly researched.

In the Renaissance the astrolabe continued to be popular, and useful. Instruments were often large and richly decorated. Meanwhile in the Islamic world, at least in Morocco, Iran and India, astrolabe making continued into the 19th century, centuries after significant astronomical activity had ceased.

In each of the Byzantine, Islamic and Christian milieus the astrolabe became a symbol of astronomy. There are some beautiful inscriptions on certain astrolabes describing it as "an icon of the Universe" (Greek), "a mirror of the stars" and "a model of the Highest Sphere together with all that is within it" (Arabic). When one holds an astrolabe in one's hand, one has the whole world in one's hand.

In early modern times the astrolabe has been replaced by the planisphere, a star chart analog computing instrument in the form of two adjustable disks that rotate on a common pivot. This can be adjusted to display the visible stars for any time and date, thus assisting the user to recognize stars and constellations. The mariner's astrolabe, a European device from the 15th

century that serves only to measure celestial altitudes and which should never have been called an astrolabe, was the predecessor of the sextant.

In modern times the astrolabe continues to fascinate, and it is an extremely useful means of teaching astronomy in schools and colleges.

Are astrolabes important?

From the point of view of the history of astronomy astrolabes are far less important than many people think. First, for timekeeping there were other instruments available, notably the sundial and little hand-dials such as the English *navicula*. Second, for timekeeping by the sun and stars, at least in the Islamic world, there existed tables with thousands or tens of thousand entries for specific latitudes. Portable instruments are, in fact, only one part of the history of astronomy, even though they are an important part.

But somehow there is a problem. For there are historians of astronomy who never mention instruments; there are some historians of astronomy who edit and translate medieval texts on the use of astrolabes without ever having seen an astrolabe. And there have been some very serious historians of astronomy who do not like colleagues who work on instruments, especially those who work on astrolabes. Such is life. In life, especially in academic life, people are also divided into the numerate and the non-numerate, and in the same way, there are folk who can grasp what an astrolabe is, and others who cannot. Then there are museum curators and instrument fanatics who know nothing of the history of astronomy. There are museum curators who cannot recognize a fake even when they catalogue it. And as we shall see, both medieval Islamic and Latin astrolabes can confuse modern researchers who do not have the necessary experience to deal with them, or, to put it another way, do not understand the language of instruments. What I mean by that may become clearer below.

A personal note

We all come to astrolabes in different ways. My academic ‘twin’, George Saliba, and I were at the American University of Beirut in the academic year 1970-71, working with Prof. E. S. Kennedy, the world’s leading expert on the history of Islamic astronomy. We learned that a visiting astrophysicist, Prof. Owen Gingerich, was going to offer a course on the astrolabe in the Spring Semester; both George and I signed up, and we were Owen’s only students. All three of us learned a lot, because George and I knew nothing about astrolabes but both of us were able to read the

Arabic inscriptions on astrolabes signed by 'Abd al-A'imma that were Owen's concern at the time, and confirm for him which pieces were genuine and which were fake. The triumvirate produced a paper together on these 18th-century Persian astrolabes. Years later in New York George and I published Owen's paper on zoomorphic star-pointers found on medieval Islamic and European astrolabes – the first study of a significant group of astrolabes with a common feature – for Ted Kennedy's *Festschrift* (1986). George went on to catalogue the Islamic astrolabes in Washington (1984) and I went on to catalogue quite a few astrolabes, Islamic and European, and to compose a lengthy essay "The neglected astrolabe" (2005) and then this wretched one, blighted by the inclusion of Part II.

How sad the middle-aged man I saw one day in the 1990s looking at show-cases full of astrolabes in the Museum of the History of Science at Oxford, the largest collection in the world. He was there when I went in in the morning to catalogue astrolabes and he was still there when I went out for lunch. He came into the pub where I was having lunch and I motioned for him to join me. "How did you find the astrolabes?", I asked. "Fascinating," he replied, "but I didn't understand a thing." In some museums in those days there were no visual aids, and in many there are still none.

Starting to understand the astrolabe

There are some good general introductions to the astrolabe and we should mention these here. Foremost is John North's splendid and timeless 1974 article in *Scientific American*. His article contains all that the average reader might want to know about stereographic projection, what an astrolabe is, and how one can use the instrument. The astrolabe booklet published by the former National Maritime Museum at Greenwich available some 50 years ago was another splendid introduction to the instrument, including information on numerous Greenwich instruments. Already decades ago folk were heard to say it was "out-of-date". Sadly this is no longer available in the Observatory bookshop; it has been replaced by an excellent but much more expensive catalogue of the astrolabe collection.

An extensive and most valuable site www.astrolabes.org was prepared by the late Jim Morrison; it is rich with information. Useful introductions by Harold N. Saunders serve the technical aspects and Darin Hayton the historical ones, respectively, with James Evans offering both. Most of the

museum catalogues mentioned below have an introductory section describing the instrument in general terms. That of Anthony Turner for the now defunct Time Museum in Rockford IL was excellent. That one does not have to be a specialist to produce an excellent introduction to the astrolabe is shown by the book on perceptions of time in the Islamic world by Barbara Stowasser.

The first part of the present study is a shorter version of my 2005 essay entitled "The neglected astrolabe", and dealing with astrolabes in both Islamic and Latin cultures. Some colleagues asked me which astrolabe had been neglected. The answer was: all of them.

Many astrolabes survive and can be seen in various museums or now on-line. Further, there is a vast amount of serious literature on the astrolabe available, which we will survey below (Part I). Perhaps one should take advantage of a current rebirth of interest in astrolabes, evident in England, with the 2014 conference in London, and Spain, with a new catalogue of all surviving astrolabes in al-Andalus and the Medieval Hispanic Christian Kingdoms. An effort has been made to at least mention most of the recent studies of the astrolabe. Notwithstanding these positive developments, there is still much scholarly literature circulating in which instruments are not given their just place or in which falsehoods about individual astrolabes are perpetuated. Worse than this is the fact that there is currently so much rubbish about the astrolabe circulating on the internet that perhaps it is worth documenting (Part II).

Educationalists have failed totally to create a new society in which people know what an astrolabe is, but I admit they have more pressing concerns. This is not completely a scholarly paper; I too have more pressing concerns. All of the references have been put into the bibliography. In Part I nothing much new is presented about the astrolabe. There is actually no need for another general article on the astrolabe. But with all the abundant reliable literature on the astrolabe that has been around for decades, it is very apparent that many people who dare to write on the astrolabe nowadays have never consulted any of it, or looked at a single astrolabe. I therefore feel compelled to gather some of the nonsense about the astrolabe which is now proliferating on the internet, not least because some of it is being generated by such dubious non-authorities as *Wikipedia*, but even by museum and university associates. It is seldom that an author tells potential readers not to waste their time reading what materials he has gathered. But perhaps the materials presented in Part II will serve as a

warning about how much false and fake information is available on internet and in popular literature, not only about the astrolabe.

Part I: What is an astrolabe

I may be repeating myself, but here goes again. The astrolabe is a versatile model of the universe, flat and usually small enough to put in one's (large) pocket. More specifically, the astrolabe is a two-dimensional representation of the three-dimensional celestial sphere, an imaginary sphere of arbitrary radius, on which it is convenient to imagine all of the celestial bodies. The "celestial" part of the astrolabe, called the rete, shows positions for the stars and the apparent path of the sun against the background of the stars. The "terrestrial" part, a set of plates for a series of latitudes, has markings for the horizon and meridian and altitudes up to the zenith. One rotation of the rete over the plate for a given latitude corresponds to one apparent daily rotation of the heavens, that is, 24 hours. The astrolabe can be made to represent the instantaneous configuration of the heavens at any time of the day or night above and below the local horizon. Its primary function is in time-keeping, since rotating the rete over any plate simulates the passage of time. Some Islamic astrolabes bear special markings on the plates for the times of Muslim prayer: sunset, nightfall, daybreak, midday and mid-afternoon. On the back of a standard astrolabe we find a device, called an alidade, for measuring the altitude of the sun or any star, as well as calendrical scales for finding the solar longitude on the ecliptic from the date in a given solar calendar, and shadow scales for deriving shadow lengths from solar altitudes and *vice versa*.

I shall not dwell here on the history of the astrolabe. Perhaps the best introduction which takes into consideration actual instruments, rather than only Greek, Arabic and Latin treatises on the construction and use of the instrument is Burkhard Stautz' introduction to his catalogue of the astrolabes preserved in the museums of Munich.

The briefest overview might look like this:

-150	Hipparchus of Rhodes knows about stereographic projection
+400	Theon of Alexandria probably develops the astrolabe
+750	Muslims encounter Byzantine astrolabes in N. Syria
8C-15C	Muslims are leading astronomers; numerous improvements to astrolabes, including astrolabic clocks; regional schools of instrument-making

+1000	First Europeans learn of the astrolabe from Muslim Spain
13C-16C	Astrolabes made in European regional schools; astronomical clocks developed. Europeans become leading astronomers in the 16C
17C-19C	Muslim craftsmen carry on making astrolabes despite scientific stagnation
17C	Europeans move on to telescope and beyond

Astrolabe retes from the utilitarian to scientific works of art

Retes are designed to include all of the sky that one can see anywhere in the northern hemisphere, and quite a bit more. The outer rim corresponds to the Circle of Capricorn, and the ecliptic is fixed between that and the Circle of Cancer, so that the entire ecliptic, the path of the sun against the background of the fixed stars, is represented. The ecliptic ring, which is not concentric with the outer ring, is graduated with the 30°-divisions of the zodiacal signs. To find the solar longitude, or where the sun is on the ecliptic, one can consult an ephemeris or read off the longitude for a given day on the solar/calendrical scales on the back of the instrument.

Already by the 10th century exquisite designs were introduced on retes, the quatrefoil decoration evolved, and zoomorphic star-pointers appeared. The rather simple, staid design of Greek and Byzantine retes gave way to retes such as we find on the magnificent astrolabe of al-Khujandî, made in Baghdad in 984. Sometimes designs went just a bit too far, except for art historians: one 12th-century Syrian astrolabe bears circus figures representing constellations, so the star-pointers are difficult to recognise. Some of these inspired European astrolabe design, so that, for example, the extensive quatrefoil decoration on an early 14th-century English astrolabe was surely derived from the Islamic and early medieval Catalan astrolabe tradition. Even at a later stage we find the "tulip" design on 16th-century Flemish astrolabe retes, which was inspired by the Arabic *basmala* = *bi-smi llâhi l-rahmâni l-rahîm*, "In the Name of God, the Merciful and Compassionate", written in Arabic "mirror" script and used on retes from 15th-century Iran.

We need not dwell on the fact that Muslim astronomers devised over a dozen different arrangements of the symmetrical ecliptic on retes. Most of these, with fanciful names, had no future, except for the "myrtle" (*âsî*) ecliptic which was occasionally used on universal astrolabes. And only one example is known, from 10th-century Baghdad, of a *kâmil* or "complete"

astrolabe, serving regions of the sky beyond the Circle of Capricorn (this time to declination 36°S).

The mater

The mater includes a raised circular ring fitted with a 360°-scale. This ring is either one piece with the the mater, or it can be riveted or brazed onto the mater. At the top it bears a throne with a suspensory ring. The name 'throne' corresponds to Greek *thronos* and Arabic *kursî*, which suggest that the instrument should be supported on the throne, analogous to a mirror standing on a pedestal. The very earliest Greek, Islamic and European astrolabes served the seven climates – see below – so that three plates and the mater itself would offer seven surfaces. Later sometimes the mater was often left empty. Sometimes, however, it might be supplied with a set of astrolabic half horizons for each few degrees of latitude. This device, invented by the leading astronomer of 9th-century Baghdad, Habash al-Hâsib, was extremely popular in Islamic instrumentation, but did not feature on medieval European astrolabes. Using the rete on this horizon plate could solve horizon-related problems for any latitude. Sometimes the mater will be engraved with astrolabic markings for the latitude of the Equator or the Tropic of Cancer, both serving didactic purposes and the latter also useful for converting ecliptic and equatorial coordinates.

Making astrolabes work "for the whole world"

The plates were originally conceived to make the astrolabe universal, serving the whole world. The Greeks divided the habitable world into seven 'climates' or latitudinal strips whose limits were defined in terms of the lengths of longest daylight at that latitude. These correspond roughly to the following latitudes:

16° 24° 30° 36° 41° 45° 48°

For this reason Greek astrolabes had seven sets of markings, one for each of the seven climates, on each side of three plates and on the mater. So did the very earliest Islamic astrolabes, and so did some of the very earliest European astrolabes. In each tradition plates for the climates were replaced by plates for a series of latitudes or specific latitudes relating to a specific locality. The "geography of astrolabes" is a key to understanding their development.

The plates bear the following markings:

- The meridian from north to south or from top to bottom, and the local horizon.
- Altitude circles for each few degrees above the horizon up to the zenith. Sometimes azimuth circles are included, these being perpendicular to the horizon and passing though the zenith.
- Below the horizon we find curves for the seasonal hours of daylight, one-twelfth divisions of the length of daylight, with which one can find the time of day from a measurement of the instantaneous solar altitude. The curves also serve the seasonal night-hours.

Markings relating to Muslim ritual (I)

Muslim ritual involves five prayers a day – sunset, nightfall, daybreak, midday or shortly thereafter, and mid-afternoon – to be performed in the sacred direction (*qibla*) toward the Kaaba in Mecca. The astrolabe can be used to determine when these prayers should begin, but only if the appropriate markings are present:

- Frequently on Islamic astrolabes we find amidst the seasonal hour curves additional curves for times of the midday and mid-afternoon prayers.
- Frequently on Islamic astrolabes we also find curves for morning and evening twilight, whose primary purpose was for regulating the times of the two prayers at nightfall and daybreak. Such curves for twilight are found on European astrolabes very rarely.

Markings relating to astrology

When the rete and plate are set to display the instantaneous configuration of the heavens above the observer, one can immediately see the configuration of the ecliptic with respect to the horizon and the meridian. The points of intersection define the ascendant, lower midheaven, the descendant, upper midheaven, thought by the credulous to be of some significance. Very rarely Islamic and late medieval European astrolabes (starting in 10th-century Baghdad, then in al-Andalus, later even as far away as England) have additional plates for determining the astrological houses and the projection of the rays, which form the basis for casting a horoscope. The rest of the operation cannot be performed with an astrolabe; one needs an ephemeris or almanac displaying solar, lunar and planetary positions for each day of a given year. It is worth an extra

sentence to repeat that one cannot draw up a horoscope with an astrolabe alone.

Markings on the back

All of the features we find on the backs of some Islamic astrolabes were introduced by Muslim astronomers, mainly in the 9th and 10th centuries, and also found on European instruments. These are:

- A trigonometric quadrant with ordered sets of horizontal lines, or vertical lines, or both, or with markings resembling graph-paper, all for performing trigonometric calculations. For example, one can use a simple approximate procedure to calculate the qibla for any location for which one has the geographical coordinates. (For more on the qibla, see below.)
- A universal horary quadrant for finding the time of day quickly but approximately, with circular markings indicating the altitude of the sun at each of the seasonal hours of daylight on any given day of the year. The result is based on a non-exact formula but is adequate in the latitudes where the device was conceived.
- An horary quadrant for a specific latitude, with graphs of the solar altitude at each year throughout the year. One measures the solar altitude and compares it with the altitudes at the hours on that day.
- The shadow square for converting shadow lengths and solar altitudes, usually to base 7 'feet' or 12 'digits'. This has multiple uses in surveying.
- Calendrical scales primarily for finding the solar longitude from the date in a solar calendar. The earliest date from ca. 900 on horary instruments made by Nastûlus. Others display leap-years and perpetual calendars, and more. On English astrolabes we often find calendars of saint's days.
- The astrological information recorded on the backs of some astrolabes was mainly useful for filling space that have would otherwise been vacant. There may be, for example, the names of the 28 lunar mansions; the names of the 12 zodiacal signs; indications of the sun, moon and planets; lengths of the limits; the lords of the faces; divisions of the faces; the lords of the day and night and the companions for each sign. This information, available in any textbook, could be learned by heart by anyone sufficiently interested.

All of these features are found on surviving astrolabes from 9th- and 10th-century Baghdad. It was mainly the universal horary quadrant, the shadow-scales, and the calendrical scales that were included on medieval European ones. Europeans do not seem to have been bothered by the fact that the universal horary quadrant did not give reasonable results in European latitudes.

Markings relating to Muslim ritual (II)

Occasionally we find special markings relating to the qibla on selected groups of Islamic astrolabes:

- If one knows the coordinates of one's locality and Mecca, it is fairly straightforward to use an approximate geometrical construction to determine a rough value for the qibla. To calculate the qibla accurately for any locality from scratch using the trigonometric quadrant is a very cumbersome procedure that is almost as complicated as calculating it using the appropriate trigonometric formula.
- A very few Iranian astrolabes display qibla directions of one or more cities in Greater Iran, marked by *mihrâb*s, in a quadrant on the back.
- Some late Persian ones from the 16th century have graphs which display the altitude of the sun throughout the year when it is in the qibla for different localities: these are not trivial.
- A solar scale, mainly on Iranian astrolabes from the 16th century onwards, showing graphically the solar meridian altitude for a series of latitudes and the solar altitude when the sun is in the azimuth of the qibla for a series of cities in Iran and for any solar longitude.
- Likewise, late Persian astrolabes have gazetteers listing longitudes, latitudes and qiblas, for dozens of cities. This information was more appropriately included in manuscripts.

The alidade and the paraphernalia

The alidade is an essential component of the astrolabe. It is a diametral rule fitted with two sights, and its pointed ends can move over the altitude scale(s). With this device one can measure the altitude of the sun (by letting the light though the hole on one sight fall on the other sight) or the altitude of any bright star featured on the rete. Equipped with this information the user can feed it into the front of the instrument. Either by finding the solar position on the ecliptic or the appropriate star-pointer and

moving it so that it lies on the altitude circle corresponding to the altitude just measured. Then the astrolabe is set for the place and the moment.

The alidade is sometimes marked with a non-linear scale for the seasonal hours of daylight for finding the approximate hour of daylight quickly for any latitude. This baby sundial is of Greek inspiration and such markings are found on early Eastern and Western Islamic astrolabes, if not medieval European ones.

A pin holds the rotatable alidade in place and passes through the mater with its plates and the rete to emerge at the front. It has a slit through which is fitted a wedge, often in the form of the head of a horse, to hold the ensemble together.

Surveying

Now with the graduated scales on the back, together with the alidade, the astrolabe could be held vertically or laid horizontally in order to solve problems of surveying, within the limits of its size. Finding the height of tall buildings, the depth of wells, or simple triangulation, all these can be theoretically achieved with the astrolabe, even though they are somewhat beneath the dignity of this noble instrument and the average astrolabe is rather too small to expect spectacular results,

Universal astrolabes

Astrolabic markings for latitude 0° are, in a sense, latitude independent. With the appropriate rule or alidade such markings become universal, that is, they can be used for any latitude. These were first developed in al-Andalus, and later a universal plate, either of the types of Ibn al-Zarqâllu or Ibn Bâso, was included among the plates of a standard astrolabe. The late-11th-century Andalusî scholar ʻAlî ibn Khalaf devised a universal astrolabe. The *maestro* Ibn al-Sarrâj of Aleppo in 1328/29 constructed a spectacular astrolabe that was universal in five different ways, a monument to human ingenuity but not something one needs every day. He was not obviously influenced by the Andalusî tradition and he far surpassed it in ingenuity. The connection between these instruments and the "Mathematical Jewel" of John Blagrave of Reading, 1584, is much clearer now that a 15th-century universal plate for latitude 52° has surfaced, auctioned at Bonhams of London in 2017.

Spherical and linear astrolabes

These can be mentioned together because they are so unusual that they were not known to the vast majority of Muslim astronomers and were unknown in Europe until the 20th century. Yet they are often dutifully mentioned in many brief modern statements about the astrolabe, never with any explanation.

Invented in the 10th century, the spherical astrolabe consisted of a globe of horary markings and a spherical cut-out rete fitted with an ecliptic and star-pointers. It could be made for a specific latitude or universal, with a latitude scale. Only three Islamic examples survive, each with its own problems, and these still need to be investigated together in the light of the available Arabic texts.

The Persian astronomer Sharaf al-Sîn al-Tûsî *ca*. 1200 invented a highly ingenious and completely functional linear astrolabe for a specific latitude, with strings attached along a *baguette*. This instrument was also known to the Andalusî astronomer Ibn Arqam al-Numayrî (d. 1259). No examples survive. The historian Ibn Khallikân mentions the linear model, pointing out that neither Ptolemy not any earlier Muslim astronomers before al-Tûsî had realized that a sphere could be represented on a line. He concludes his discussion by mentioning the futility of trying to represent the sphere on a point.

The boat astrolabe

Various exotic non-standard astrolabes, with ecliptics composed of partly northern and partly southern markings, were described by al-Sijzî (*ca*. 1000) and again by al-Bîrûnî (*ca*. 1025) and again by al-Marrâkushî (*ca*. 1280), with new variations in Najm al-Dîn al-Misrî (*ca*. 1325). The relevant text of al-Marrâkushî was translated in the 1840s by L.-A. Sédillot, which enabled the illustrations to appear in several 20th-century writings on the astrolabe without any explanation of what they represented. The 1922 German translation of the relevant part of al-Bîrûnî's treatise by Joseph Frank did not help. In the 1980s the astrolabe types unique Istanbul manuscript of al-Sijzî's treatise were surveyed by Richard Lorch, again in German. Najm al-Dîn's treatment was translated and commented upon by François Charette. One result of this difficult situation is that even historians of Islamic science have referred to these astrolabes as "degenerate" when they are merely exotic and rather impractical. One particular astrolabe variety has suffered more than any other, namely, the *zawraqî* or "boat" astrolabe. It has even been confused

with the 14th-century English instruments called the *navicula*, with which it has nothing in common aside from the name.

The rotatable horizon is fixed on the rete of the *zawraqî* astrolabe, indeed it is part of it. Its two halves can serve different latitudes. A mast rises from the middle of the bottom of the boat-shaped horizon and includes a ring to be attached at the centre. The ensemble rotates over a stereographical projection of the stars and the ecliptic. The motion is precisely equivalent to the stars and ecliptic on a regular rete moving over a plate of astrolabic markings. Two sights can be fitted on the horizon so that it can function as an alidade. Obviously only horizon-related problems could be solved with this instrument. However, in several late Indo-Persian an adaptation of this is found. The relatively small horizon is fixed on the rete near the central ring. There is a small circle at the centre of the plate bearing a stereographic projection of the stars and the ecliptic, within the regular astrolabic markings for a specific latitude. In this case the horizon is too small to be fitted with sights. The correct interpretation of the *zawraqî* markings is to be found in S. R. Sarma's new catalogue of Indian instruments.

How to make an astrolabe

The astronomical markings on an astrolabe be constructed with a straight-edge and compass, with the components – mater, back and plates – laid out successively on a board. The individual circles can be constructed one after the other using a geometrical procedure. However, this was not the only way: they also used tables.

A very useful auxiliary trigonometric function was tabulated by al-Khwârizmî in early-9th century Baghdad. But it was his contemporary al-Farghânî who, using such a function, compiled tables of coordinates for constructing the circles on astrolabes and their plates: these showed the centre distance and radius of the altitude and azimuth circles, both for each degree of altitude and azimuth, and for each degree of latitude, a total of some 13,000 entries. (Muslim astronomers also constructed tables of radial coordinates to facilitate the construction of hyperbolae on sundials. Neither kind of astrolabe nor sundial tables are known from medieval Europe.)

How to use an astrolabe

This not the place to go into any detail on such a topic, not least since there are plenty of works where the reader can find this information. If one has used the alidade and altitude scale on the back to measure the altitude of

the sun or a given star, it suffices to put the solar marker or the star-pointer on the rete on top of the appropriate altitude circle on the appropriate plate: the astrolabe then displays the instantaneous configuration of sky above the observer. Do this twice and the amount by which the rete has been rotated will be a measure of the time elapsed between the two observations. The potential of this device should be obvious. Around the year 1000 the Shiraz astronomer ʻAbd al-Rahmân al-Sûfî lists 1,000 uses of the astrolabe; he was pushing his luck, because in another redaction of his astrolabe treatise he listed but 386 uses.

The geography of astrolabe-making and the leading astrolabists

The leading places of astrolabe production, marked * if they are hypothetical, and printed bold if there was also serious activity in astronomy, are as follows:

C4-C6	Alexandria*	
C6–C11	Constantinople*	
C7–C8	Harran	
C8–C13	**Baghdad**, then also **Isfahan**	
C11	**Córdoba, Toledo**	Catalonia
C13	**Granada, Seville, Marrakesh**	
C14	**Granada, Aleppo, Damascus**	**London & Oxford**
C15		**Paris**, then **Vienna**
C16-C17	Isfahan	Madrid, Flanders
C17	Lahore	
C19	Jaipur	

This list is based on subjective judgement, is questionable and very debatable, and will surely be subject to revision.

The following list may be of interest, not least since many of the names may be unfamiliar to Europeans and certainly to Muslim readers. The list of Muslim astrolabists from the 8th, 9th, and early 10th centuries is well known, although only the one woman in the list is ever cited in the modern literature. These are the leading makers of astrolabes and related instruments over the centuries, whereby we should keep in mind that most medieval European astrolabes are undated. All dates are approximate.

850	**Baghdad**	Habash al-Hâsib (only treatises survive)		
900	**Baghdad**	Nastûlus		
950	**Baghdad**	Hâmid al-Wâsitî		
1000	**Isfahan**	Ahmad & Muhammad sons of Ibrâhîm		
1100	**Baghdad**	Hibat Allâh al-Baghdâdî		
1200	**Seville**	al-Khamâ'irî		
1200	**Marrakesh**	Abû Bakr ibn Yûsuf		
1225	Isfahan	Muhammad ibn Abî Bakr al-Fârisî		
1225	**Damascus**	'Abd al-Karîm al-Misrî / al-Ba'labakkî		
1325	**Aleppo**	Ibn al-Sarrâj		
1300	**Granada**	Ibn Bâso		
1325			**London** `	"Sloane A"
1350	**Damascus**	Ibn al-Shâtir		
1400			**Paris**	Jean Fusoris
1425	**Samarqand**	Jalâl al-Kirmânî		
1450			**Vienna**	Regi / Dorn
C16/17	Isfahan	M. ibn Muqîm Yazdî *et al.*		
C17	Lahore	Allâh-dâd and descendants		

The most significant early treatises on the construction and/or use of the astrolabe are:

C6-13	Constantinople	Miscellaneous Greek texts (Anne Tihon)
825	**Baghdad**	al-Khwârizmî (François Charette & Petra Schmidl)
850	**Baghdad**	al-Farghânî (published w/ English transl. by Richard Lorch)
1000	**Shiraz**	al-Sûfî (no translation published)
1000	Madrid ?	al-Majrîtî / Pseudo-Mâshâ'allâh (no translation published)
1025	**Ghazna**	al-Bîrûnî (no translation published)
1280	**Cairo**	al-Marrâkushî (partial French translation J. Sédillot)
1325	**Cairo**	Najm al-Dîn al-Misrî (translated, François Charette)
1360	Paris	Pèlerin de Prusse (Robert Fisher & Edgar Laird)
1390	**England**	Geoffrey Chaucer (various edns. & transls. in mod. Engl.)
1400	**Paris**	Jean Fusoris (Emmanuel Poulle)

1530 Nuremberg Georg Hartmann (John Lamprey)

Reception and transmission

There are so many studies of the reception of the astrolabe in this culture or that, and so many on the transmission of the astrolabe from one culture to another, too many, one might argue. Virtually all of them are based on Greek or Arabic or Latin texts on the construction or use of the astrolabe, and virtually none of them are based on actual astrolabes or groups thereof. Thus, for example, people have written on the astrolabe on Byzantium, ignoring the only surviving Byzantine astrolabe because they wrongly think it is not Byzantine. People write about the Muslim reception of the astrolabe without looking at any of the many surviving early Islamic astrolabes. People write about the European reception of the astrolabe without looking at any numerous Andalusî astrolabes or early European instruments. Only texts are sacred, some would claim. And Latin texts are so sacred that nobody who edits a medieval Latin text on the astrolabe feels the need to translate them into a modern language. And astrolabes and astrolabe texts are not so closely related as some people think, so in order to understand the reception or transmission of the astrolabe one does actually look at a few astrolabes as well as a few texts:

- The stars we find on medieval European retes as often as not do not correspond to the stars listed in Latin star-tables taken from Arabic sources.
- We question certain medieval latitudes without realizing that they are nothing other than *calculated* latitudes of the climates (for various values of the obliquity of the ecliptic).
- Many researchers do not recognize the climates and their latitudes if these are disguised, without the word ‘climates’.
- Folk find a table in an instrument treatise and have no inkling that such tables have a history of half a millennium.
- Nobody asks the questions like why do the earliest Spanish astrolabes bear so little resemblance to Andalusî astrolabes?
- What did French astrolabes look like before Fusoris?
- Are there any early Italian astrolabes?

- Where did the magnificent Sloane astrolabe come from, being far more technically and artistically advanced than later medieval English astrolabes?
- Is there anything original on any medieval European astrolabe (to *ca*. 1500) that is not attested on an early Islamic piece, except, of course, some decorative items and Easter scales and saint's days (only English)?

For all these reasons I shall not dwell on reception and transmission. Taro Mimura has recently published a paper entitled "Too many Arabic treatises on ... the astrolabe ... ". It is satisfying that now at last we have an overview of the instruments in the 13th-century *Libros del saber de astrología*. Meanwhile I am giving a lecture in Granada this December, 2017, on Renaissance instruments with Islamic precedents which nobody knows about, so I do not think the topic is without interest, and it is certainly not closed.

Research on medieval "Islamic" and "Christian" astrolabes

Already in the 19th century various orientalists prepared detailed and accurate descriptions of some particularly important Islamic astrolabes. These included the Frenchman Frédéric Sarrus, two Germans Bernhard Dorn and Franz Woepcke, one Spaniard Eduardo Saavedra, and the Englishman William Morley.[2] Morley published in 1856 the magnificent Sloane Persian astrolabe in the British Museum. Very few medieval European astrolabes were published, mainly by antiquarians, for example, C. H. Read, Secretary of the Society of Antiquaries, London. In 1893 he published a medieval "Spanish" (actually Catalan) astrolabe that had shortly before been presented to the Society.

A major boost to the subject of Islamic instrumentation was achieved by the Sédillots, father-and-son, in Paris in the early 19th century. They had access to the splendid manuscripts of an enormous compendium on instrumentation compiled in Cairo *ca*. 1280 by the Maghribî astronomer Abû 'Alî al-Marrâkushî. The father Jean-Jacques translated most of the treatise dealing with spherical astronomy and sundials, and the son Louis-Amélie summarized the remainder of the text dealing with astrolabes, quadrants and other instruments. Nothing like this was published therefter

---

[2] Reprints of studies on Islamic instruments from the 19th and early 20th century – a monumental total of over 5,000 pages (!) – are found in Frankfurt publication *AIOS*: *Arabische Instrumente in orientalistischen Studien*, 12 vols., 1990-98.

until François Charette in 2003 edited and translated the 14th-century instrument compendium of the Cairene astronomer Najm al-Dîn al-Misrî.

During the period 1923-45 Robert Gunther published his monumental 14-volume work *Early Science at Oxford*, of which one volume contains masterly accounts of the medieval instruments preserved in Oxford. In 1932 Gunther published his monumental overview of some 300 astrolabes, Islamic and European, mainly from the Oxford collection, but drawing on information from other collections, not only the British Museum. Alas his knowledge of Arabic was not up to the task, and he was not well served by the Oxford Arabists from whom he sought help. As a preface he wisely included a facsimile of Morley's account of the Sloane Persian astrolabe. If his descriptions of Islamic instruments were often problematic, it was not least because, in the spirit of the time (which lasted till the demise of the Shah and still continues), he put "Persian, Indian, Hindu" astrolabes before "Arab" instruments, thereby distorting completely the development of the astrolabe in the Islamic (and Indian) worlds. But his treatment of European astrolabe was sometimes fraught with deficiencies. His section on medieval "Spanish astrolabes" consisted of the London SA piece and an Oxford piece, which was clearly Northern French. His section on English astrolabes was inevitably better than the others, and his description of the magnificent English Sloane astrolabe shows him at his best. For decades the field relied on Gunther and auction catalogues and exhibition catalogues. Gunther has been indispensable over the centuries, but it is not the last word, as its principal title *Astrolabes of the World* would tend to make one believe.

A survey of the history of astronomy and instrumentation in the German-speaking world was published by Ernst Zinner in 1967. Elsewhere, histories of astronomical instrumentation have tended to focus on principal figures: Chaucer of 14th-century England (John North and numerous others), Jean Fusoris of 14th-century Paris (Emmanuel Poulle, but no-one since), Regiomontanus of 15th-century Vienna and elsewhere (again Ernst Zinner), and inevitably Copernicus, who surely had an astrolabe but it is not one of those now preserved in Cracow. The 1947 article by Baxter D. Wilson on the astrolabe and English life in the Middle Ages is still worth reading, not least because it contains no hype.

Catalogues of major collections

A handlist of all astrolabes was prepared by Derek de Solla Price in 1972 but published only privately. In the following survey of catalogues of astrolabe collections, authors dealing with Islamic and Latin objects are separated thus //. Reliable catalogues are now available for the collections in the following locations:

Washington NMAH (George Saliba // Sharon Gibbs), Rockford, Ill. TM (Anthony Turner), Greenwich NMM (François Charette // Koenraad van Cleempoel), Madrid MAN and other Spanish collections (Salvador García Franco, and now Azucena Hernández Pérez – see below), Nuremberg GNM (King), London NG (Francis Maddison), Munich DM (Burkhard Stautz), Paris IMA (Jeanne Mouliérac), and Chicago AP (David Pingree // Roderick & Madge Websters), as well as for very small collections in Bernkastel-Cues (J. Hartmann), Frankfurt (Silke Ackermann & Petra Schmidl // Reinhard Glasemann), Kassel (Petra Schmidl), Leiden (Robert van Gent), Utrecht (van Cittert), Naples MC (Ornella Marra), Strasbourg OBS (Francis Debeauvais & Paul-André Befort).

Astrolabes in Oxford MHS and Florence MG are inventoried online.

Each of these catalogues represents a mammoth achievement on the part of the authors and a substantial contribution to our knowledge.

Selected studies

In the course of the past few decades the following topics have been addressed:

- the star-names of astrolabe-stars and related star-tables in medieval Arabic and Latin manuscripts (Paul Kunitzsch), sometimes tested on actual instruments (Elly Dekker, King, Burkhard Stautz);
- star-position on retes (Dekker, Stautz);
- the design of retes, quatrefoil decoration (King, taken up again by John Davis), zoomorphic star-pointers (Owen Gingerich, Sreeramula Sarma);
- the tables of coordinates used by Muslim astronomers for marking circles on astrolabe plates (King);
- the latitudes of the climates and the latitudes of localities used on plates (King);
- tables of longitudes, latitudes and qibla-directions on Persian (King) and Indian (Sarma) astrolabes;

- the universal horary quadrant and underlying formula for timekeeping (King), and latitude-specific horary quadrants (Mercè Viladrich);
- universal astrolabes and universal plates (*safâ'ih*) in the Andalusî tradition of Ibn al-Zarqâllu (Roser Puig) and Ibn Bâso (Emilia Calvo);
- astrological tables (Willy Hartner, Silke Ackermann);
- calendrical tables (Ackermann);
- problematic inscriptions (Rachel Ward, Mohammed Abu Zayed & King & Petra Schmidl)
- metallurgical investigations of individual instruments (Robert Gordon, Brian Newbury, Gerard Turner, John Davis);
- textual transmission from Byzantium to Islamic world (Paul Kunitzsch, Anne Tihon);
- instrumental transmission from Byzantium to Islamic world (Burkhard Stautz)
- the precarious attempts at dating astrolabes by means of the First Point of Aries on calendrical scales (Henri Michel, Emmanuel Poulle, Gerard Turner, Giorgio Strano)
- textual transmission from al-Andalus to Europe (Kunitzsch, Julio Samsó & colleagues, Emmanuel Poulle, Guy Beaujouan, & many others)
- instrumental transmission from al-Andalus to Christian Spain (Azucena Hernández)
- instrumental transmission from al-Andalus to the Islamic East (François Charette)

Bio-bibliographical studies of astrolabe-makers and their works

Most Islamic astrolabes are signed and many are also dated. A monumental contribution to the study of Islamic astrolabes, at least to *ca*. 1500, was made by the prolific Israeli orientalist Leon A. Mayer in his *Islamic astrolabists and their works*, published in 1956. For each maker, Mayer listed all of the known instruments made by him with a full bibliography. His work is a model publication, but it inevitably became more out-of-date with each the appearance of each new catalogue. A revision of this valuable research tool was made in the 1980s by the French antiquarian Alain Brieux together with Francis Maddison, then curator of the Museum for History of Science at Oxford. There is apparently still some hope that

their long-anticipated *Répertoire des astrolabistes et leurs oeuvres* will appear in print. A similar undertaking for medieval European astrolabes would have been inconceivable since most are neither signed nor dated.

The Frankfurt medieval astronomical instrument project

A project in Frankfurt organised by the present author during the 1990s made considerable progress in the documentation of medieval Islamic and European astrolabes, quadrants and sundials to *ca*. 1500. (Late Islamic, Indian, and Renaissance European instruments were deliberately omitted.) The project was generously funded during 1992-96 and 1998-2001 by the German Research Foundation (Deutsche Forschungsgemeinschaft). Hundreds of astrolabes were catalogued and their descriptions, if adequately completed, are available upon request. Illustrations of early Islamic astrolabes have been scanned, those of European astrolabes alas not. The catalogue in its entirety could not be put online, because so many parts were incomplete. Copies of the text are available with this author, Petra Schmidl, Benno van Dalen, François Charette and Silke Ackermann. The project ceased to function when funding ran out, the participants (Ackermann, Maier, Stautz, Charette) became scattered, and our institution was closed. The two parts of the table of contents of the catalogue have been published separately; they were inevitably easier to generate than the catalogue itself.

The major collections investigated – **only for medieval instruments, including astrolabes and quadrants, Islamic and European** – were New Delhi, Cairo, Kuwait, Istanbul, Rome, Florence, Milan, Paris, Strasbourg, Madrid, Barcelona, Brussels, Nuremberg, Frankfurt, Munich, Berlin, Cracow, London, Oxford, Cambridge, New York, Washington, Rockford IL and Boston, as well as particularly important minor collections such as Athens, Brescia, Genoa, Turin, Pavia, Venice, Toulouse, Copenhagen, Cologne, Schweinfurt, Edinburgh, Dublin, Innsbruck, Salzburg, Vienna, Graz, Prague, Leiden, Cambridge MA, Damascus, Aleppo, and also Hyderabad, as well as the major private collections, those being in Belgium, Italy and the US. Not visited were personally were Tehran, Baghdad, Rabat, Fez, Stockholm, Kassel, Salem MA.

Major problems, often insurmountable, were obtaining decent photos and then storing them efficiently. Museum hours were generally constricting and often there were just too many astrolabes and too little time. The record was set in Salzburg where Dr. Christa Svoboda of the Museum

Carolino-Augusteum let me work in her office several hours after closing time and served my wife and me dinner there when I was finished.

In the course of the Frankfurt project, apart from the budding catalogue, certain astrolabes of singular importance, known as "the landmark astrolabes", various collections of astrolabes, and groups of related astrolabes, as well as quadrants and sundials, were studied in detail. What has been published from the catalogue or relying Stockholm, on it are the following:

- a new description the sole surviving Byzantine astrolabe from 1062, with new insights into its arrival in Italy and its relationship to the 1462 astrolabe of Regiomontanus;
- all Eastern Islamic astrolabes up to *ca*. 1100;
- the descriptions of all Western Islamic astrolabes up to *ca*. 1200 have been superseded by the new descriptions of Azucena Hernández Pérez – see below;
- many important later Islamic astrolabes, including those of the Yemeni ruler al-Ashraf, the Nuremberg circus-figures astrolabe, various pieces made for Ayyubid and Ottoman sultans, and another for the Sultan Ulugh Beg;
- a group of spectacular astrolabes, quadrants and sundials from medieval Syria (prepared for the 1993 Paris IMA exhibition on Syria);
- the earliest European astrolabe, from 10th-century Catalonia, and all later medieval astrolabes from Catalonia;
- the sole surviving astrolabe with inscriptions in Judaeo-Arabic, that is, Arabic in Hebrew script, related to an earlier Catalan astrolabe with inscriptions in Latin with Catalan influences;
- many individual astrolabes from Spain, Italy, France, England;
- survey of all astrolabe retes, Islamic and European, with quatrefoil decoration;
- the 14th-century Toledo astrolabe, with inscriptions in Hebrew, Latin and Arabic;
- the earliest known German astrolabe, from Einbeck and datable *ca*. 1330;
- all of the earliest Vienna astrolabes, focusing on the 1462 Regiomontanus piece (with Gerard Turner).

In addition the retes of dozens of astrolabes, Islamic and European, were analyzed using computer graphics and the results compared with available star-lists (Stautz).

Some particularly spectacular instruments have still not been researched adequately, or their descriptions are not yet publishable. For example:

- the astrolabe with astronomical tables on the plates (*zîj al-safâ'ih*) and moving parts for an equatorium, invented by Abû Ja'far al-Khâzin, this example made in 1120 by the renowned Hibat Allâh al-Asturlâbî, lost after World War II, first studied in the 1970s from incomplete photos (King), resurfaced in Berlin MIK, together with the unique copy of the associated text, preserved in Srinagar, and recently investigated (Emilia Calvo);
- the quintuply-universal astrolabe of Ibn al-Sarrâj of Aleppo, dated 1328/29, by far the most sophisticated astrolabe ever made, preserved in Athens BM, together with the available texts on its inevitably very complicated use, book-length publication in preparation since 1975 (François Charette & King);
- the 14th-century N. French astrolabe with solar-lunar gear mechanism which came to light since 2000 and which is far more sophisticated than the one in London SM known already to Gunther (Koenraad van Cleempoel).
- the albion associated with Regiomontanus, datable Vienna 1450-60, preserved in Rome AA, briefly studied (Emmanuel Poulle) but awaiting detailed investigation;
- the 15th-century N. European universal plate auctioned at Bonhams of London in 2014.

Catalogue of Indian instruments

More recently, all Indian and Indo-Persian astronomical instruments have been catalogued on-line, a monumental feat still in progress, by Sreeramula R. Sarma. This is a model production, complete with a historical introduction and overview and close to 4,000 pages of text. Some 300 astrolabes are included, all described in detail. Prof. Sarma achieved this single-handed, with his son Ananda organizing hte website, and he writes in his introduction, "had I known the enormity of the project, I would probably not have ventured in the first place". Fortunately he achieved this very valuable contribution whilst continuing to produce his other publications on instruments. In addition he has included in his

catalogue large extracts with translation from Mahendra Sûri's *Yantrarāja* of 1370, which is the first Sanskrit manual on the astrolabes.

How to illustrate an astrolabe

In the old days, all but a few museums would photograph astrolabes as pieces of metal-work so as to convey the overall impression of the instrument. Inscriptions and components were of no consequence so it did not matter that they could not be seen. And the alidade invariably had to be attached on the front of the astrolabe lest it be overlooked. To give credit, even then Oxford and Florence could make decent photos of any object.

Nowadays things should be different. The full front and back should be shown, with the astrolabe at the side of the back. Ideally the empty mater and each side of each plate should be photographed. Also the main inscription on the back if there is one. Again images should be detailed enough so that all star-names on the rete and all inscriptions on the plates can be clearly seen. Images of a single plate are better than no images of plates. Such images can serve to identify schools or individual makers and/ or locations, where these are in doubt.

What one should do with such images is another matter.

Astrolabes with more than one layer of inscriptions

It has long been apparent that instruments with more than a single set of inscriptions have the potential to be more historically significant than those that have never been reworked. Take the Destombes astrolabe with one set of Latin inscriptions from the 10th century and a second set from the 14th (?) displaying Catalan influence. Take the Berselius astrolabe with an original set of markings from 14th-century monastic Picardy and an additional set from 16th-century Humanist Liège-Louvain. Take the monumental astrolabe from the mid 17th-century for the Moghul Emperor Shâh Jahân with additional Sanskrit markings. Two recent studies also come to mind.

••EDITOR FIX PAGE FORMAT ON THE NEXT PAGE - space on the right may result from a hidden illustration••

The first by Kurt Maier, Arabist and Romanist. A remarkable Islamic astrolabe in the Jagiellonian University Museum in Cracow is dated Córdoba, 1054/55. Unlike most Andalusî astrolabes, it is unsigned. On the five plates and mater there are 11 sets of astrolabic markings for latitudes between Hadramawt (beginning of the 1st climate) and Saragossa.

Additional markings in Latin with Catalan variants render the Arabic star-names and the names on signs and months, and three plates have inscriptions CARDEYA, TORTOSA and PPYA, for Cartagena, Tortosa and Perpinyà - Perpignan. The Latin forms of signs, such as ARIAS and ACARI show Catalan influence and are attested in the astronomical treatise of the Majorcan Ramon Llull of 1297. However, the additional markings, which have a very medieval look bout them, are punched, and there is even a single punch for the ligature AL, which is used to render some of the Arabic star-names. Maier thought perhaps 15th century? But there is more. How did this Arabic-Catalan astrolabe come to Cracow? There is, in fact, a historical connection between Catalonia and Cracow, but alas I've forgotten what it was.

Astrolabes with replacement parts

An Ottoman astrolabe from *ca*. 1700 now in the Museum of Islamic Art in Doha looks like an Ottoman astrolabe. But when one takes it apart, one finds all of the plates are much earlier, about 600 years earlier, from an 11th-century Andalusî astrolabe. The plates serve range of latitudes from 23° (Mecca) to 45° (Constantinople), with altitude circles for each 9°. An additional set of astrological markings serves latitude 35°, and the corresponding regular plate for that latitude is marked Ceuta, Tangiers, Sicily, Mosul, Manbij and Qum. Under the Hammûdids in the first part of thee 11th century Ceuta and Tangiers were united with Algeciras and Málaga in a single principality, which may point to the place of manufacture. However, the biggest surprise of all was an astrolabic plate for latitude 16°30' south, corresponding to Anti-Meroë, corresponding to the middle of the first climate in the southern hemisphere and the lowest limit of the inhabited world in the three cartographic grids associated with Ptolemy of Alexandria. The existence of one replacement Ottoman plate indicates that one Andalusî plate has been replaced: perhaps this had markings for 0°/90° and 66°/72°, which would have made this a truly universal set of plates, unparalleled amongst known astrolabes.

Already Gunther noted an unusual rete on an early European astrolabe in Oxford (#191), and to his credit he wrote that it was "an interesting instrument on account of the alterations or additions to the original design". His predecessor Lewis Evans, who purchased the piece in Paris,

had already recognized an Islamic connection. (Many investigators have spurned such instruments, as have private collectors.) The rete has an Islamic look about it, not least because there are two *mihrâb*s in the lower half. The plates are a mess, with some bearing altitude circles for each 5°, others for each 9°, and others for each 12°. Recently Petra Schmidl turned her attention to this piece, one could say with an unfair advantage because a few years before she had catalogued an astrolabe by a highly competent astrolabist Ibrâhîm al-Sahlî of Valencia in 1086, now preserved in Kassel, which has an identical rete to the Oxford piece. (The truth is that cataloguing instruments brings rewards; Derek Price started his passion for instruments by cataloguing the instruments in the British Museum, and his passion increased when somebody else published his catalogue.) The Oxford rete has been reworked with Latin inscriptions and fitted in a French (?) mater. One of the plates is labelled for Saragossa, two others for Paris. Schmidl diligently traces an itinerary Valencia — Saragossa — Paris — Oxford for this remarkable astrolabe, and her article is appropriately entitled "Knowledge in motion".

Regional studies

The expression "material objects" covers things like pottery, glassware and metalwork, but inspires little confidence. In German there is the word "Realienkunde" which means the same thing but sounds much more convincing. In Krems on the Danube there is an Institute for Realienkunde of the Middle Ages and Early Modern Period. In 1993 they organized a conference attended by Islamicists, Byzantinists and Medievalists. Following a lecture of mine on medieval instruments, a saucy colleague commented "Sehr schön, und ... ?", meaning "Very nice, but so what?". Most people don't know that Vienna was the most active centre of astronomy in the world in the 15th century; I didn't think I needed to stress that in Austria. I had been to Austria on several research trips, so, in the conference proceedings published by the Austrian Academy of Sciences, I appended to my paper two critical lists which I thought might answer my colleague's question, the first a list of all medieval instruments in or stolen from Austrian collections, and the second of all instruments from 15th-century Vienna in museums around the world. After the lists had been in available for some 25 years, John Davis was the first person to use them and to find to his surprise a 14th-century English astrolabe preserved in Innsbruck. No such lists exist for any other country in Europe.

A major contribution to the field is the brilliant and extremely useful 2017 Madrid doctoral dissertation including a detailed catalogue of all Islamic and Christian astrolabes from al-Andalus/Spain to *ca*. 1500, including close to 50 pieces (Azucena Hernández Pérez). This deals with artistic aspects of the instruments as well as the technical aspects and raises all manner of questions for future research. Q1: why does the earliest Latin astrolabe, from 10th-Catalonia, bear no resemblance to any early or later Islamic pieces? Q2: why do none of the other medieval Spanish astrolabes bear much resemblance to earlier Andalusî astrolabes?

Some other recent contributions

Very few astrolabes bear signs of extensive use, many bear no signs of use whatsoever. So they often served as gifts and collectors' items. François Charette has considered the main locales where Islamic instruments were ordered, made, sold, used, explained, modified, rejected, or admired, in an attempt to provide a sense of the manifold dimensions of the material culture of science in Islamic societies. His contribution focuses on 9th- and 10th-century Baghdad and beyond (Iraq and Iran) and 14th- and 15th-century Cairo and Damascus.

In recent years, for the first time since Gunther, serious attention has been paid to various early English astrolabes, not only to technical details but also to artistic considerations and cultural context (John Davis). In particular, new studies have been published of:

- the monumental Sloane astrolabe in London BM, made in London ca. 1325, with extensive quatrefoil decoration;
- various medieval English astrolabes with Y-shaped or quatrefoil retes.

A doctoral dissertation completed in 2016 discussed aspects of various, but by no means all, medieval English astrolabes, relating them to the Chaucer manuscript tradition (Seb Falk). The most interesting English astrolabes from a technical and an artistic point of view have yet to be investigated as they deserve to be.

Petra Schmidl has identified the reworked rete of an early medieval astrolabe as the work of a well-known Andalusî craftsman. The Arabic inscriptions of the original had been obliterated and replaced with Latin ones. This opened up the way for an investigation of the itinerary of the rete.

A catalogue of the few (10?) surviving astrolabes with Hebrew inscriptions has been promised for several years (Josefina Rodríguez Arribas), and

numerous useful contributions are found in a volume of proceedings of a 2014 London conference, "Astrolabes in medieval cultures".

Catalogues of medieval French, Italian, German and English astrolabes have yet to be prepared. An AHRC project "All the astrolabes" is apparently to be launched in England (Silke Ackermann).

Again, astrolabes were not the only instruments in medieval times. Catalogues and surveys and numerous studies are available of medieval celestial globes, Islamic (Emilie Savage-Smith) and European (Elly Dekker). Numerous individual medieval Islamic sundials have been published (Louis Janin, King), and very few non-trivial medieval European sundials are known to have survived.

From geared astrolabes to astronomical clocks

A unique example of an astrolabe fitted with a geared mechanism for reproducing the relative motions of the sun and moon survives from 13th-century Isfahan, made by the highly-competent and innovative Muhammad ibn Abî Bakr al-Rashîdî al-Ibrî. We also possess an account of a similar mechanism by the early-11th-century scholar al-Bîrûnî, and various earlier treatises survive but have not been studied yet. The precise relationship of this kind of mechanism to earlier Greek and Byzantine devices, as well as to later European ones remains to be established. Some Italian texts of the early 14th century, if not earlier, provide evidence of the design of astronomical clocks of a highly complex variety with extensive gear mechanisms to reproduce solar, lunar and planetary motions. They seem to represent an Islamic tradition for which we have no evidence from the Islamic world itself. It is known, however, that in 1232 ambassadors of the Ayyubid Sultan al-Ashraf presented to the Emperor Frederick II, whilst in Southern Italy, a kind of planetarium which had "within itself the course of the planets". A large device for timekeeping resembling an astrolabe was seen by a 14th-century historian in the home of the contemporary Damascene astronomer Ibn al-Shâtir, and the face of a water-driven astrolabic clock originally made in Fez in the late 13th century survives (in a later replacement) to this day. These two instruments and a text in the *Libros del saber* are testimonials to an Islamic tradition on which we have virtually no other information. An inscription preserved in Palermo mentions a *majâna ma'a asturlâbih*, "a waterclock with its astrolabe", apparently made for a Merinid Sultan in 1363. [This paragraph taken from *Synchrony*, II, pp. 66-68.]

On the history of the astronomical clock in Europe there is abundant literature.

Associating astrolabes with their original provenance

Recently, various studies have appeared attributing individual astrolabes to patrons or owners. For example, there is a splendid 15th-century astrolabe preserved in Copenhagen, on which the name on the dedication to a prince has been deliberately effaced. There are silver-inlaid azimuth curves for the qiblas of Samarqand and Herat marked on two plates. I have argued that this piece was dedicated to the later Sultan Ulugh Beg, who as a prince oscillated between those two cities. His astrolabe was made by a well-known Iranian astrolabist who, it turns out, was later the instrument-maker at the Observatory in Samarqand.

In the past few years there has been a welcome revival of interest in English astrolabes. John Davis has painstakingly investigated various medieval English astrolabes seeking clues to their origins not only from such unmistakable features as latitudes and localities on the plates from such cryptic features as the saint's names on the calendrical scales, which indeed turn out to have regional flavours. In particular, he has uncovered some of the background of the magnificent Sloane astrolabe from the British Museum, more sophisticated than any of the Chaucer instruments, concluding that it was associated with King Edward III *ca*. 1326. His investigation still does not explain how the most sophisticated medieval English astrolabe could have preceded other more mundane pieces from the same milieu.

Relating specific instruments to the associated manuscript tradition presents challenges of its own, not least since most medieval European astrolabes are unsigned (and undated). Catherine Eagleton has considered some of the available astrolabes in English collections which are in the "Chaucer" tradition, comparing details on them with the illustrated manuscripts in the Chaucer tradition. "Chaucer's own astrolabe" is somewhat exaggerated for her title, and already in the 'abstract' it becomes"not so much 'Chaucer's own astrolabe' as 'an astrolabe just like the one belonging to Geoffrey Chaucer'".

Some astrolabes declared fake that are not fake

An astrolabe in the Metropolitan Museum of Art in New York purports to be signed by the Yemeni Sultan al-Ashraf in 1295. In the 1950s it was declared a fake by a leading historian of science in the US who said "there

was no astronomy in the Yemen". In fact there was, and the present author's first book was entitled *Mathematical Astronomy in the Yemen* (1983) and was based on some one hundred Yemeni astronomical manuscripts. Appended to a substantial treatise on the construction of astrolabes, extant in Cairo, there is a statement by two of his teachers affirming the excellence of six astrolabes that he made. One of these is clearly the MMA piece. The Museum still does not have an appropriate webpage for this jewel and does not mention that it has been published down to the last detail.

The French naval officer Marcel Destombes had a real feel for historical instruments. In the early 1950s near the Spanish border he purchased a medieval astrolabe which immediately sparked his interest. He thought it was the earliest surviving astrolabe with Latin inscriptions, and he published it in 1962 as such, claiming it came from 10th-century Catalonia. His article raised a furore amongst certain academicians in Paris, innocent of the language of instruments, who set out to demolish both him and his astrolabe. Destombes died in 1983, bequeathing all of his instruments to the Institut du Monde Arabe in Paris rather than any French museum. In 1993 a special session of the International Congress on the History of Science met in Saragossa, and various scholars were able to pronounce on it: one had found the original inscriptions were of a genre found only in 10th-century Catalonia (Mundò); another found that the secondary inscriptions from the 14th century involved Catalan influence on the Latin (Maier); another showed that FRANCIA, the name found on one of the plates for latitude 41°31', corresponded to the Arabic *bilâd al-Ifranj*, meaning "Land of the Franks", that part of the peninsular not under Muslim rule at the time (Samsó), and another showed that the piece bore no resemblance to any early Eastern or Western Islamic astrolabes or to any early European piece (King). In brief, Destombes was right.

Another very old astrolabe in the Nikolaus Kusanus-Stift in Bernkastel-Kues on the Moselle could be from the 10th, 11th or, at the latest, the 12th century. It is very basic and has, unfortunately, no rete. Appropriately, plates for each of the seven climates. I see no way to localize its provenance, but it makes me think of the well-known, very charming story about Radolf, a monk from Liège, and Ragimbold, a monk from Cologne. Both of these men had studied with Fulbert of Chartres (*ca*. 960-1028), student of the celebrated Gerbert d'Aurillac (*ca*. 946-1003), later Pope Sylvester II, who earlier had come into contact with Muslim scholarship in

monasteries of Catalonia. Around the year 1025 Radolf in Liège invited Ragimbold from Cologne to come and examine an astrolabe he had acquired. Ragimbold replies that he cannot come to Liège but could they please send the astrolabe to Cologne so that he can inspect it. The Liège monk replies that they cannot part with their astrolabe, not only because it is their model for making other astrolabes, but further they will not send it to Cologne because there is nobody there who could understand it.

In 1959 the British historian of science and expert on historical instruments Derek de Solla Price published a description of an astrolabe on loan to the National Maritime Museum in Greenwich as "the first scientific instrument of the Renaissance". According to a Latin inscription this beautiful little instrument with an angel on the back was presented by "Ioannes" to the Greek Cardinal Bessarion in Rome in 1462. Now the Ioannes could only have been Ioannes de Monte Regio, known as Regiomontanus, the foremost astronomer in Europe, who accompanied the Cardinal from Vienna to Rome about that time. In 1989 the owner offered it to Christie's for auction, and an accurate, detailed description was prepared by Gerard L'E.Turner. The piece sold for close to £250,000. But then doubts were raised by the press and would-be experts about its authenticity, what with the "absurd" angel and the "*latin de cuisine*" of the dedication, and the purchaser returned it to Christie's. All doubts were allayed when it was realised that the piece was one of a dozen astrolabes made in the Vienna workshop and the whole lot were published by Turner and the present author in 1994.

Years were to pass before it was realised that the dedication was an acrostic, with hidden meanings that would be of interest to donor and the recipient, some referring to the 1062 Byzantine astrolabe which Bessarion seems to have brought with him from Constantinople. I doubt that there is a more brilliant Latin inscription from the Renaissance. And it was finally realised that the angel engraved on the back of the astrolabe represented the 5th-century St. Bessarion, from whom the Cardinal had taken his name when he became a monk, since the saint was venerated as an angel in the Byzantine liturgy. And there is much, much more, too much, indeed, for art historians, too much for science historians or Renaissance scholars, and certainly for Dan Brown, for here we have the key to the most enigmatic painting of the Quattrocento: a Latin acrostic coupled with an angel. In the meantime even specialists on the history of astronomy are repeating the erroneous assertion of scholars over 50 years ago concerning the 1062

Byzantine astrolabe. These had never seen an astrolabe but when they saw a bird on illustrations of the Byzantine astrolabe, claimed that it "apparently reveal(s) Oriental influence". In fact, it reveals many things, but no "Oriental influence".

Other astrolabes deemed important because they have been misinterpreted

Other instruments have basked in the limelight for decades without meriting it. In the Museo Galileo in Florence there is preserved an Islamic astrolabe with some extraneous undatable European markings on the back (an electrotype exists in the Museo Naval de Madrid, which has caused much of the confusion). In the late 19th century the Spanish scholar Eduardo Saavedra associated it with Pope Sylvester II, the Frenchman Gerbert d'Aurillac who studied in Córdoba in the 10th century. Gunther was rightly suspicious of this pedigree. Much rubbish has been written about this piece in the past century, mainly in exhibition catalogues. In fact, we can safely associate it with 10th-century Baghdad, but for some reason the back was never finished there. It was messed up by a European sometime between the 14th century (if the additions are genuine) and the 19th century (if the additions are fake) and provided with a case with a dubious Latin inscription purporting to relate to the 13th century. I tend toward an early date because of a fraction that occurs on a calendrical scale, which makes me think of the Toledo astrolabe, the earliest known occurrence. This piece is the most commonly and persistently exploited astrolabe as a symbol of the glory of Arabic science in al-Andalus, when in fact it comes from Baghdad, probably has nothing to do with al-Andalus, and even less with a French pope. It seems that this astrolabe is no longer being associated with Gerbert in the scholarly literature. However, it keeps cropping up all over the place, as *the* astrolabe representing the transmission of Islamic astronomy to Europe.

Making instruments count – a personal account

Making instruments count was the title of a *Festschrift* for Gerard L'E. Turner published in 1993. Gerard came to instruments in Oxford and became the expert on microscopes. He later moved to Elizabethan instruments. It was during the course of the fiasco surrounding the "unique" Regiomontanus astrolabe in the mid 1980s that he taught me many things about European instruments (and I taught him where to find ten more from the same Vienna workshop). My contribution to Gerard's

Festschrift was a paper entitled "Rewriting history through instruments: The secrets of a medieval astrolabe from Picardy". This astrolabe had been known to Gunther *ca.* 1930 (#202), when it was in a private collection in England, and he remarked on the curious numerical notation that was used on it. The astrolabe could have been acquired by Oxford in the 1950s when it first came up for auction at Sotheby's, but after several attempts it did not sell and was sold privately to a French collector, who then kept it for decades without letting anyone publish it. When I first saw this astrolabe in the 1990s I was fascinated by the ingenious number-notation in which each numeral from 1 to 9999 is represented by a unique cipher. A number-notation which virtually nobody knew about?? There were a couple of articles on it by colleagues who had found the notation used or recorded in medieval Latin manuscripts, but that was a closed door for me, or so I thought until I realized that these manuscripts, and others, were mainly of Cistercian provenance. I also thought there was a problem with the medieval French month-names, but my colleague Kurt Maier

informed me they were in medieval Picard. The instrument is clearly 14th century French, or rather, Picard, but it bears a later inscription indicating that it was given by one Berselius to one Amerotius in 1522, and of course I had no idea who there two individuals were. Things changed when I found both of them in the index of a book on Erasmus one day whilst browsing in Blackwell's in Oxford. Paschasius Berselius was a Benedictine monk from Liège and Hadrianus Amerotius was his teacher of Greek at the *Collegium Trilingue* in Louvain, and the latter had published a small book on number-notations. The first fruits of these endeavours were presented to Gerard, who had taught me how to look at European instruments. But there are many more instruments that are full of surprises: in 1995 I gave a lecture to the Scientific Instrument Society in London entitled "Making instruments talk – Some medieval astronomical instruments and their secrets". I still maintain that this is an exciting field in which to work.

The mariner's astrolabe, unrelated to the 'real' astrolabe

When is an astrolabe not an astrolabe? When it is a mariner's astrolabe. The navigational instrument known as the mariner's astrolabe is not an astrolabe. The mariner's astrolabe is to a 'real' astrolabe as a donut is to a multi-layered wedding-cake or an English Christmas cake. The former should never have been called an astrolabe – its name is well explained by

a favourite Spanish expression of mine, "obstinación historiografica",[3] meaning something like "a misnomen which stuck for centuries and still won't go away". The instrument serves only to measure solar or, with any luck, stellar altitudes. All known examples of the so-called "mariner's astrolabe"– some 68 pieces – were documented by Alan Stimson in 1988. A new project has been launched to document the entire corpus Castro *et al*.). Confusion between the mariner's astrolabe and the planispheric astrolabe is on the rise as the press greets the booty of each newly-discovered shipwreck from the 16th, 17th or 18th century as an astrolabe, and some people who write on the mariner's astrolabe have no idea what a 'real' astrolabe is – see Part II. The mariner's astrolabe was indeed eventually replaced by the sextant.

The mariner's astrolabe was used for navigation. It can only be used for measuring solar and stellar altitudes.

Modern astrolabe copies

The best copies available these days are those made by Martin Brunold in Switzerland (www.astrolabe.ch). These are based on actual historical instruments, usually those with special historical importance, and of course are signed and dated by Brunold, who has done great service to the astrolabe.

Prof. Fuat Sezgin of Frankfurt has had dozens of copies made of Islamic and European astrolabes and related instruments for his museum of the history of Arabic-Islamic science. Several of these were made by Martin Brunold. The general impression made by these copies on somebody who has seen real astrolabes will vary between wonder and horror. The copies

[3] I owe this expression to Fernando Arce-Sainz, "The alleged Basilica of Saint Vincent of Córdoba: From a historical myth to an obstinacy of historiography", *Al-Qantara* 36 (2015): 11-14.

are often stripped of plates and superfluous features. The accompanying text – in German, French, English and Arabic – is informative and contains illustrations and descriptions of the instruments (www.ibttm.org/ENG/museum/collection/2-3.pdf). The descriptions are as faithful to the partial copies as they can be but the bibliographical notes are inadequate. The spectrum of astrolabes featured is, on the other hand, impressive indeed.

Is it really so difficult to understand what an astrolabe is?

No, because one can understand it from several points of view. One does not need to be a rocket scientist.

A wee bit of history will be useful. High-school mathematics is certainly a help but not a necessity. More important is a basic knowledge of the way in which the Heavens appear to rotate about a celestial axis and about the way in which the sun unseen moves against the background of fixed stars. This cannot be taken for granted.[4]

Fortunate readers may be able to benefit from an astrolabe workshop conducted by an expert such as Dr. Hüseyin Sen (listed in uu.academia.edu/HuseyinSen). Otherwise, various websites offer introductions to the astrolabe and its use. The most useful and most complete is the website www.astrolabes.org of the late Jim Morrison. It deals with both the construction and use of the instrument, and it respects both historical texts on the instrument and the surviving astrolabes themselves. It is also one of the few that contains any reference to the vast bibliography on the subject. I single out five others that can be recommended, one by Emily Winterburn for MuslimHeritage.org, another with Tom Wujec giving a reasonably-well informed TED talk on how to use a Chaucer-type astrolabe, and another with music instead of commentary from the Institut du Monde Arabe in Paris. There is a French site compiled by people who know what an astrolabe is and how it works, namely, that of the association called Méridienne at Nantes. A German Muslim site about Islam has a page on the nature and use of the astrolabe in which virtually every single statement, be it historical or scientific, is correct. Quite a few more will be mentioned in Part II, mainly to demolish them.

*****

---

4 At New York University in the early 1980s, I had some students ask people on Washington Square: “On which day of the year is the sun directly overhead in New York?”; the replies were fortunately never published.

In concluding this brief overview of non-fake news about astrolabes, we should remind the reader that both in the Muslim world and in Christian Europe, other instruments were used besides astrolabes, namely, globes and armillary spheres, quadrants, sundials, and other instruments harder to classify. And then there are large-scale observational instruments, the purpose of which was to assist in improving astronomical parameters and tables, the latter being the main tool of astronomers from Antiquity through to the Renaissance and beyond. Serious timekeeping, at least in the major Muslim cities, involved the use of extensive tables computed for specific latitudes; to use some of them one needed to know the solar altitude and the solar longitude. Presumably an astrolabe would serve the former, and the latter would be best known from an ephemeris. Very few such tables are known from medieval Europe, but they become more widespread in Renaissance times. And although many people might claim to ‘like’ astrolabes, very few people like tables.

Fig. 1: The front of the magnificent astrolabe of the astronomer Hâmid ibn al-Khidr al-Khujandî, dated 374 Hijra, that is, 984/85. The simple design of the earliest Islamic astrolabes, adopted from Byzantine astrolabes, has here been developed into a scientific work of art. The throne shows two splendid lions (from Persepolis?). There are 33 stars on the rete, all standard astrolabe stars, several with zoomorphic pointers. A charming quatrefoil perhaps betrays Byzantine influence and remained a feature of astrolabe retes until the Renaissance. The plates serve latitudes 21° (for Mecca) then each 3° from 27° to 42°. The back, which, more than most astrolabes, shows signs of use. In the upper left there is a trigonometric quadrant with horizontal parallels for each 1°. In the upper right there is an horary quadrant for latitude 33°, which is one of the latitudes used for Baghdad since the time of al-Khwârizmî. Now al-Khujandî is usually associated with al-Rayy (modern Tehran), but this feature of his astrolabe proves that he spent time in Baghdad. Below the horizontal diameter is a series of astrological tables displaying: the names of the 28 lunar mansions; the names of the 12 zodiacal signs; indications of the sun, moon and planets; lengths of the limits; the lords of the faces; divisions of the faces; the lords of the day and night and the companions for each sign.

This astrolabe was published by the author in detail in Kuwait in 1995 and again, together with all other surviving Eastern Islamic astrolabes till *ca*. 1100, in 2004 (*Synchrony*, XIIIb: 503-517). The piece is now in the Museum of Islamic Art, Doha, Qatar. [Photo courtesy of a previous owner.]

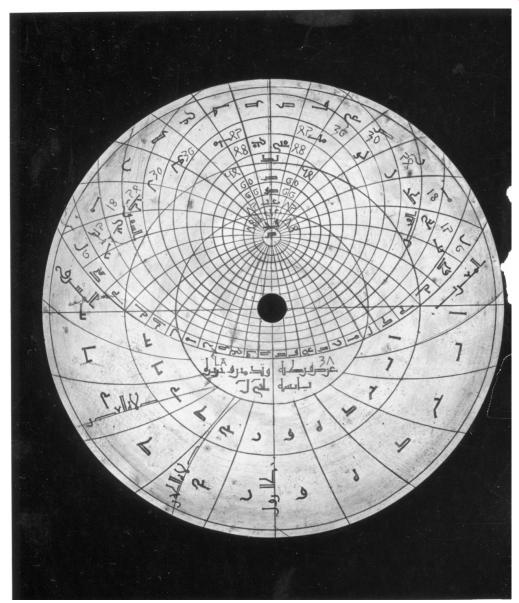



Plate 2a: One of the plates on what is perhaps the oldest surviving Andalusî astrolabe, that is, from the 10th century. This piece is preserved in the British Museum, but has yet to be acknowledged for what it is, probably because is unsigned and undated. The rete has the appearance of an Eastern Islamic astrolabe, which is precisely what one would expect. It is this plate that concerns us here. It bears altitude circles for each 6° and azimuth circles for each 10°. The underlying latitude is 38°30’ and is here associated with Córdova, Tudmir (Murcia) and Ibiza. The western horizon is marked *al-maghrib*, the eastern one *al-mashriq*, the meridian as *al-zawâl*. Amidst the curves for the seasonal hours below the horizon we find curves for the *zuhr* prayer and the *‘asr* prayer. The circle for altitude 18° above the horizon is marked *al-fajr* (daybreak) on the left and *al-mughîb* (nightfall) on the right. These markings suffice to determine the times of all five of the daily prayers. There are additional markings by a European all over this piece. He has messed up the rete and not completed his attempt to remove the Arabic inscriptions.On this plate he has engraved in “Western” numerals the altitude arguments and has misinterpreted the latitude as “LA 37”. [Image courtesy of the British Museum.]

5th VERSION
17 January 2018

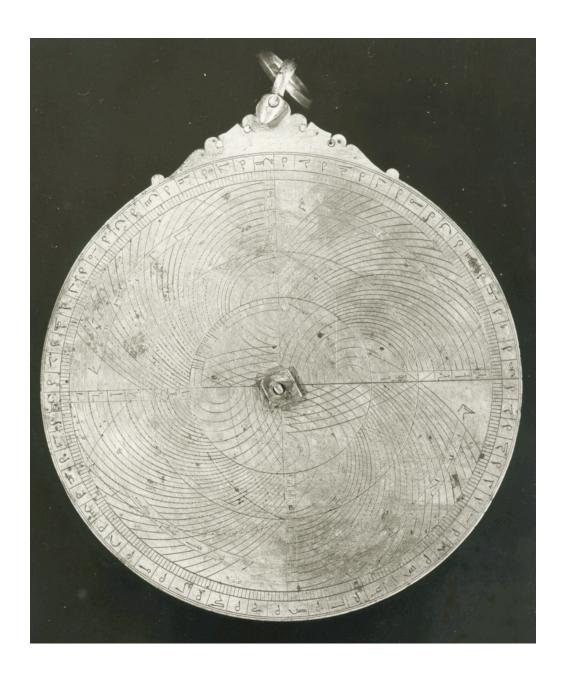



Fig. 2b: Some of the instruments made by Muslim astronomers have defied interpretation in modern times. With markings such as these on a 14th-century Syrian astrolabic plate, surely conceived and constructed by one of the leading astronomers in that milieu, we have come a long way from the standard astrolabe. Practical and easy to use is this astrolabic plate for multiple latitudes not. Preserved in the Deutsche Staatsbibliothek, Berlin. See *Synchrony*, XIVb: 709-712.

5th VERSION
17 January 2018

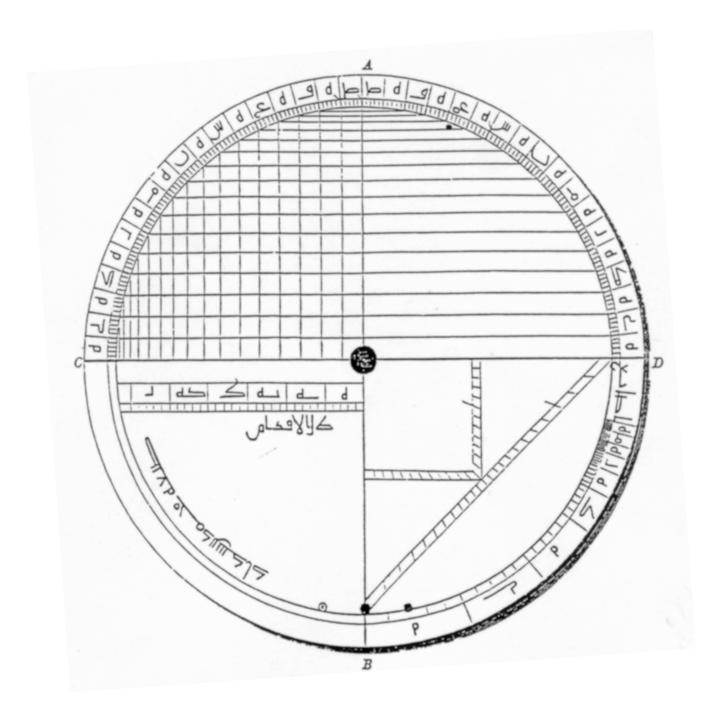



Fig. 3a: The back of an astrolabe made in Baghdad in the early 10th century by Muhammad ibn Shaddâd al-Baladî. In the mid-19th century the piece belonged to Dr. J. G. Wetzstein in Berlin, at one time consul in Damascus, but it is now missing. Fortunately, it was published by the orientalist B. Dorn, "Drei arabische Instrumente" (1865), pp. 115-118. There are two trigonometric quadrants above the horizontal diameter. In the lower left there is a scale for horizontal shadows to base 7 situated at 7 out of 60 units below the horizontal diameter (such a scale was introduced by al-Khwârizmî). In the lower right there are three shadow scales for the reader to interpret. Only one plate was available, with markings for latitude 11° (Aden) and 21° (Mecca). The original rete was missing. See now *Synchrony*, XIIIe: 484-487. Notice that 19th-century lithographs of astrolabes are more useful than 20th-century photos.

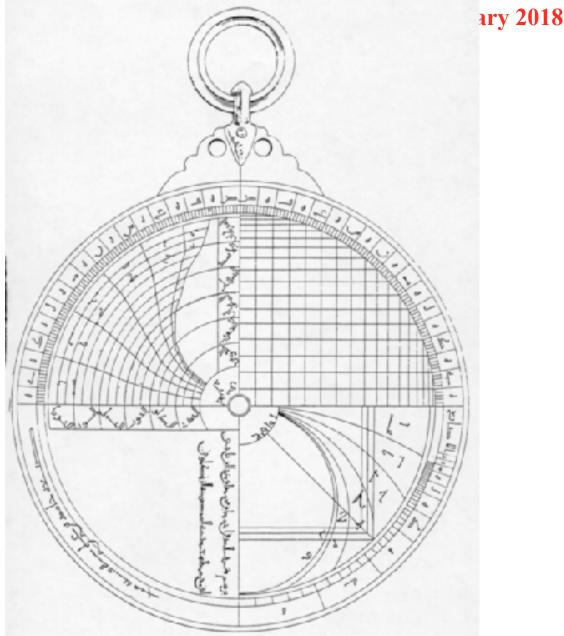



Fig. 3b: The back of an astrolabe made by the renowned instrument-maker Hâmid ibn ʻAlî al-Wâsitî in Baghdad in the year 343 Hijra, that is, 954/55. Here we see a spectrum of newly-introduced features designed by Muslim astronomers in the 9th and early 10th centuries to fill the void on the back of Byzantine astrolabes. First in the upper left we find an horary quadrant for latitude 33°, serving Baghdad. In the upper right we find a trigonometric quadrant. In the lower right we find two sets of markings which journeyed together from the 9th century to the Renaissance. These are the universal horary quadrant, for finding the time of day quickly by means of an approximate formula that works quite well in the latitude where it was derived (but not in Europe), and the double shadow square, with divisions on the perimeter. This happy couple of instruments reappear, for example, on the universal horary dial, for example, on the 14th-century English *navicula*. Only the mater of this astrolabe is known to have survived into the 19th century. Inside the mater there are astrolabic markings for a series of horizons which constitute evidence that the there missing rete was of the *kâmil*, "complete" variety, including stars outside the Circle of Capricorn and with declination down to 36°S. Lithographs of both sides of the mater – of better quality than most photographs of instruments produced by museums in the 20th century – were published by the Sicilian orientalist Vicenzo Mortillaro in 1848. It was stolen from the Museo Nazionale in Palermo in the mid 20th century. For a detailed description see *Synchrony*, XIIIe: 496-503.

**5th VERSION
17 January 2018**

Fig. 4: A Renaissance Italian astrolabe datable to *ca*. 1600. Various features of the rete and throne reflect aspects of al-Khujandî's astrolabe. The flame-shaped star pointers betray French influence, since these are a feature of the astrolabes of Jean Fusoris (Paris *ca*. 1400) and a broad spectrum of later instruments based on these. The present location of this piece is unknown. The image is taken from de Vries, "Some notes for the use of an astrolabe".

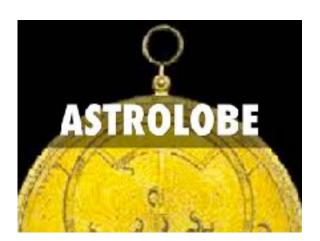
Part II: What an astrolabe is not

Readers genuinely interested in astrolabes should not read this section of my paper. It will make them weep. It is of no scientific interest. But it relates a story in keeping with our times: those who create fake news do so because they cannot face or handle the truth. The citations below show how far some moderns can stray from the truth when writing about things they know nothing about or spend no time trying to find out about. Behind all of the quotes is, on the one hand, an arrogance in thinking that on historical objects one can write any old rubbish / n'importe quoi / lauter Blödsinn / ayyi kalâm and get away with it, and, on the other, an ineptitude to access the most accessible of the many internet sites dealing with the instrument properly. If one simply googles the word astrolabe one comes straightaway to the pathetic *Wikipedia* page, on which see below, and then to Jim Morrison's recommended site. In Part I we have mentioned numerous reliable websites and detailed catalogues of astrolabe collections and several thousand pages of scholarly articles on medieval astronomical instruments. All of this has not hindered the proliferation of much nonsense about astrolabes on the internet.

The concerned reader might ask why did I waste my time with all this nonsense. In fact, it did not take long to collect the following quotes from the internet, and anybody could dig out even more such useless material. Most of the quotes are in English, which reflects the nature of the Web: there are, for example, as many *Wikipedia* pages in English as there are in French, German, Spanish and Italian put together. A frightening thought is that a similar undertaking could be done for other subjects. And the first subject that is most poorly represented on the internet is the history of Islamic science, not by "malevolent orientalists", but by well-meaning but hapless Muslim university students who have no conception of the vast literature on the subject and no idea about the most accessible websites already in existence.

The confusion about the astrolabe begins with the fact that the word "astrolabe / astrolabio / Astrolabium" is derived from the Greek, meaning something like "taker of the stars", as far as that means anything in translation. It is not fully clear in Greek either, but it seems that it means something like "measurer of (the altitudes of) the celestial bodies, namely, the sun and stars (with the alidade)", with the purpose of "correctly placing

their representations on the rete with respect to the horizon and meridian on top of the appropriate plate". In any case, that is what an astrolabe does. Ptolemy called the armillary sphere an astrolabe, so perhaps he thought of the name as a generic word for a series of instruments that combined observation with representation of the instantaneous configuration of the heavens. A serious modern Greek site on the substantial scientific and technological achievements of the Ancient Greeks refers in a moment of weakness to the armillary sphere as "The astrolabe of Ptolemy (the G.P.S. of the ancient Greeks)".[5] For some curious reason the site does not mention the "real" astrolabe of Theon.

The Muslims used the name *asturlâb*, and my 1981 paper on the origin of the astrolabe according to the medieval Arabic sources[6] is probably the most-cited paper I ever wrote, possibly because it is the least significant, for a lot of what the Arabs wrote about the word itself was fantasy. The same holds for much of what we find in the non-specialised literature and the internet today. I particularly like the pronunciation "astrolobe", which I often hear.[7] At a cocktail party in Frankfurt in the 1990s a lady asked me how my work on Skylab was progressing.

5 http://kotsanas.com/gb/exh.php?exhibit=1301005 (accessed 2017).

6 King, "On the origin of the astrolabe according to the medieval Islamic sources" (1981), with a new version in *Synchrony*, XIIIe: 575-611.

7 The illustration is from https://www.haikudeck.com/astrolobe-uncategorized-presentation-eadf4a7632.

The biggest problem we now confront is that there are two completely different instruments with the name “astrolabe”. As we shall see, these are often either confused one with the other, or amalgamated into a single instrument. The person who first applied the word “astrolabe” to that trivial European device which we now call “mariner’s astrolabe” should perhaps have been made to walk the plank.

Some of the blame for astrolabic misinformation lies with the museums themselves. The largest collection of Islamic (and European) astrolabes, namely, Oxford (MHS), does have a website featuring individual instruments. However, the next largest collections, Doha (MIA) and Washington DC (NMAH) and Greenwich (NMM), do not even have on their websites a clear statement of what an astrolabe is or what one can do with it. Greenwich used to have a splendid booklet offering all one really needs to know about the astrolabe and giving a list of their own astrolabes; this is apparently no longer available at the Observatory bookstore. The lavish scholarly catalogue of their astrolabes is an expensive alternative for any visitor.

The best the Islamic Art Museum in Doha can do, after having spent a king’s ransom to purchase several dozen medieval Islamic astrolabes, is to claim that the astrolabe is:[8]

> “a medieval scientific instrument used for astronomical calculations and navigation.”

What on earth are “astronomical calculations”? The astrolabe is not a calculating machine. And it should be generally known, but it is not, that **the astrolabe was not used for navigation**.

This kind of sloppiness facilitates the circulation of such more detailed misinformation as we find in a recent London auction catalogue offering an 13th-century Islamic astrolabe:[9]

> “Astrolabes were widely used in the Islamic world both for navigation and for finding the qibla, or direction of Mecca. They were used to find the time of sunrise in order to help schedule morning prayers. … ”

---

8 http://www.discoverislamicart.org/

9 “A rare Andalusian brass astrolabe, Islamic Spain, 13th century, probably before 1238”, at https://www.bonhams.com/auctions/24197/lot/116/?category=results&length=90&page=1 (accessed 2017).

This text has been circulating for decades, and it is time to put an end to it.

- In fact, **astrolabes were not used at all in navigation in the Islamic world**.
- Most Islamic astrolabes have no means whatsoever for determining, in the sense of calculating the qibla. If one knows what the qibla direction is, then one can find out the qibla on any horizontal scale laid out in the cardinal directions. A very few astrolabes have special markings for finding the qibla – see Part I.
- The claim about sunrise and the morning prayer (at daybreak) is naïve, for if you determine the time of sunrise, the time for the morning prayer, at daybreak, is passed. (On many Islamic astrolabes there are indeed special markings on the plates for each of the five times of prayer: sunset, nightfall, daybreak, midday, mid-afternoon.)

Consider this description of an actual astrolabe, this a 13th-century Andalusî piece preserved in a museum in Istanbul:[10]

> "Historical sources indicate that the astrolabe was invented by the Greek astronomer Hipparchus in the second century BC. The most advanced types of astrolabe were used by the Muslims of al-Andalus and the Maghreb. Astrolabes are astronomical instruments used for measuring time and distance. Their plates bear engraved concentric circles, meridians and astrological terms and numerals. Invented in the 2nd century BC, the most advanced astrolabes were used by the Muslims in al-Andalus and the Maghreb."

Here we have the fiction that the Muslim astronomers of al-Andalus and the Maghrib used the most advanced astrolabes. This contradicts all that we know about Islamic astrolabes, the most sophisticated having been made in Iraq, Iran and Syria (9th-14th centuries). The inclusion of the Maghrib goes beyond the popular myth that the most important scientific advances were made in al-Andalus rather than anywhere else. And how can you measure "distance" with an astrolabe, distance of what? Astrolabic plates have more circles than a few ones, only one meridian, no "astrological terms", whatever that may mean, and certainly numerals, not to confuse but to guide the perplexed.

10 Anonymous, "Astrolabe", at http://www.explorewithmwnf.org/pc_item.php?id=object;ISL;tr;Mus01;25;en&lng=en

The inclinometers of *Wikipedia*

Claims like these, and others yet more far-fetched, such as the use of the standard astrolabe for planets and eclipses[11] and casting horoscopes or even for time-keeping by the moon,[12] have been circulating in the popular literature since the 1950s and are now common on the web. Thus, for

Just a reminder.

---

11 The special plate for determining eclipses (*safîha kusûfiyya*) is, of course, an exception: see Johannes Thomann, “Astrolabes as eclipse computers: Four early Arabic texts on construction and use of the *safîha kusûfiyya*”, in *London 2014 Conference Proceedings*.

12 Father William (Sean Connery) in the film *The Name of the Rose*.

example, the English *Wikipedia* article on the astrolabe is pathetic (and the French, Italian, Spanish and Dutch versions are not much better, whereas the German version is excellent):

> "an elaborate inclinometer, historically used by astronomers and navigators, to measure the inclined position in the sky of a celestial body, day or night. It can thus be used to identify stars or planets [!], to determine local latitude given local time [!] and vice versa, to survey, or to triangulate."

The same author seems to have also written the article "Inclinometer" for *Wikipedia*, for there we read:

> "Astrolabes are inclinometers that were used for navigation [!] and locating astronomical objects [!] from ancient times to the Renaissance."

The astrolabe is not an inclinometer, what a ridiculous word! The astrolabe can, however, be called an inclinometer if one has no idea what it can be used for, as in this case. In addition, we note:

- Medieval users of astrolabes had no need to "identify stars" or to "locate astronomical objects". They might measure the altitude of a particular star and then place the marker for that star on the rete on top of the appropriate altitude curve on the plate beneath. They would then have an image of the instantaneous configuration of the heavens above their horizon, which is very good for a start.
- The principal use of the astrolabe is not "to determine local latitude given local time" but to determine the time of day or night for one's own latitude by observing the altitude of the sun or a particular star. Rotating the rete simulates the passage of time.
- I have been claiming for almost half a century that **standard astrolabes were not used for navigation**. I am perhaps wasting my time.
- The use of the astrolabe for surveying and, if you must, triangulation, involves fairly trivial applications of the alidade together with the altitude scale and the shadow scales on the back of the instrument. This all works better in theory than in practice since astrolabes are usually too small for such operations.

Astrolabes used for astrology

Astrology is mentioned again as the main function of the instrument in a museum site:[13]

> "There were two main types: the mariner's astrolabe used for navigation – to determine the altitudes of the sun and stars; the planispheric astrolabe, the most common instrument, was used for astrological purposes. ... ..."

I repeat, the astrolabe was not (only) used for astrological purposes. The most one can do with it is to position the sun and to determine the astrological houses. For the rest one needs an ephemeris or almanac to find the positions of the moon and five naked-eye planets. Or one needs special plates.

The great advantage of astrology is that at any stage of casting a horoscope a mistake will not influence the chance of the outcome being accurate. A series of videos showing the use of astrolabes in astrological calculations have been prepared by Dr. J. Lee Lehmann. I have seen one purporting to "calculating house cusps",[14] which left me quite confused.

Emily Winterburn's otherwise reasonable treatment of the astrolabe, mentioned in Part I, suggests that:

> "to cast a horoscope, it is necessary to know the position of the stars visible in the sky at the time of birth."

But it is the sun, moon and five naked-eye planets which supposedly influence affairs on earth, and if one has an astrolabe one can do no more than determine the twelve houses, starting with all-important ascendant (the point of the ecliptic instantaneously rising over the horizon). From then on, one needs an ephemeris – a set of tables showing for each day of the year the ecliptic positions of the sun, moon and five naked-eye planets – to see which houses the seven bodies are in and then to establish their interactions and their influences.

---

13 Nimira Devi, "Astrolabe, one of His Highness the Aga Khan's favorite artifacts at the Museum" (2014) at https://ismailimail.wordpress.com/2014/12/22/astrolabe-one-of-his-highness-the-aga-khans-favorite-artifacts-at-the-museum/ (accessed 2017)

14 J. Lee Lehman , "H35 Astrolabe and Calculating House Cusps" (2012), at https://www.youtube.com/watch?v=qoWwDtTUiz4 (accessed 2017).

One series of videos in French on astrology deals with "The astrolabe, symbol of the astrologer."[15] I have not investigated these beyond noting the succinct and correct introduction to the astrolabe:

> "L'astrolabe est le cousin de la sphère armillaire. C'est la version portative. L'astrolabe est un outil conçu par les grecs. C'est une projection de la sphère armillaire dans un plan. L'astrolabe était indispensable à l'astrologue car il permettait de lire l'heure de jour comme de nuit. C'est grâce à lui que l'astrologue pouvait "faire l'horoscope", étymologiquement "examiner l'heure". ... ." // "The astrolabe is the cousin of the armillary sphere. It is the portable version. The astrolabe is a tool conceived by the Greeks. It is a projection of the armillary sphere in a plane. The astrolabe was indispensable to the astrologer because it enabled (him) to read off the time of day or the time of night. It is thanks to the astrolabe that the astrologer could cast a 'horoscope', the word meaning 'examine the hour'. ... ."

James R. Lewis is the author of *The Astrology Book – An Encyclopedia of Heavenly Influences*, published in 2003. On the astrolabe he had the following to say:[16]

> "An astrolabe is a mechanical device that, prior to the development of the sextant, was widely used by mariners. Said to have been developed by Hipparchus, greatest of the ancient Greek astronomers (although some scholars give Ptolemy the honor), the astrolabe was used by astrologers when they erected horoscopes to determine the positions of the planets. ... ... Originally Greek, this instrument was lost to western Europe until its reintroduction by Arabic sources."

There is almost too much nonsense in this account for me to know where to begin. But I feel obliged to say a few words. The astrolabe was developed neither by Hipparchus nor by Ptolemy. The mechanical device called an astrolabe was not used by mariners. The astrolabe was not used by astrologers to erect horoscopes. When one does erect a horoscope one does not determine the positions of the (sun, moon and) planets. I love the phrase "lost to western Europe", for when the Europeans did encounter the astrolabe they did not have the astronomical knowledge to fully appreciate

---

15 Anonymous, "L'astrolabe, symbole de l'astrologue", part of series of videos entitled *Renaissante astrologie*, at https://www.youtube.com/watch?v=Isr7ieC069s (2016).

16 James R. Lewis, *The Astrology Book – An encyclopedia of heavenly influences*, Canton MI: Visible Ink Press, 2003, p. 70.

it. The astrolabe was not reintroduced anywhere in Europe. (Classical Greece can hardly be put on the same continent as Dark Age Europe.) And it was not reintroduced by Arabic sources. It came to the attention of a few enlightened Europeans in Northern Spain who were captivated by its – for them – originality. A reliable history of astrology cannot be written by believers, a situation not restricted to astrology.

The noble name Astrolabe has been hijacked by a group of American astrologers,[17] who refer visitors to their site to the site of Jim Morrison for information on the instrument.

Clueless academics on the astrolabe

The spectacular exhibition "*Circa* 1492" in at the Naitional Gallery of Art in Washington in 1992 included the magnificent British Museum astrolabe by ʻAbd al-Karîm al-Misrî, made in Damascus (?) or Mayyafariqin (?) in 1235/36. The renowned historian of Islamic art J. Michael Rogers wrote the description in the catalogue. Although he could handle the decoration and the inscriptions, Michael was unable to present a viable account of what an astrolabe actually is:[18]

> "The astrolabe, the most important astronomical instrument of the Middle Ages, was designed to measure the altitude of the stars, moon [!] or sun without any mathematical calculation [!]. It was used in much the same way as the astronomical quadrant [!] or sextant [!], but in addition it bore various diagrams [?] or scales [?] which made it possible to determine immediately the positions of the sun, moon and planets [!] – most significant, the earth [!] – in relation to the fixed stars [!]."

Where Michael got the clever idea that with an astrolabe one could determine the position of the Earth I do not know. Why not ask a specialist? Francis Maddison of the Museum of History of Science in Oxford contributed to the same exhibition. In his detailed account of the rete and back Michael completely ignored the plates, which hold the key to the enigmatic geographic provenance of the piece.

---

17 Anonymous, "A brief history of Astrolabe", at https://alabe.com/history.htm.

18 *Washington NGA 1992 Exhibition Catalogue*: *Circa 1492 – Art in the age of exploration*, Washington DC, 1991, p. 215.

A medievalist website, which one would expect to be halfway serious, has recently discovered that the astrolabe is a "medieval multi-tool of navigation", the "Swiss Army knife of medieval travellers".[19]

Some students at the University of Oklahoma, using the *Wikipedia* article but hopefully without the help of their professor, have this year (2017) posted the following uses of astrolabe:[20]

- to identify stars [how can you identify a star in the sky by looking at a rete?] or planets [!];
- to calculate the position of celestial objects [?];
- to determine local latitude [!] given the local time [!] and vice versa [it is the vice versa which is the most important use of the instrument];
- to measure the time of the year [really?];
- to compute what part of the sky is visible [how can you compute that? certainly an astrolabe reveals it at a glance];
- to predict celestial events such as eclipses [that would be really clever since the moon is not featured on the astrolabe];
- to triangulate current location [no, one can determine the position of a distant location by measuring its direction from two different locations relative to the line between them];
- and it can be used at night or day [*contra* several sites which maintain the astrolabe can only be used at night [!]].

The National Museum of American History, home to the largest astrolabe collection outside Europe, has a description of their 1537 astrolabe by Georg Hartmann of Nuremberg[21] which begins: "

> "The astrolabe is an astronomical calculating device used from ancient times into the eighteenth century. Measuring the height of a star using the back of the instrument, and knowing the latitude, one could find the time of night and the position of other stars. ... ."

The implication is that the astrolabe can only be used for timekeeping at night.

---

19 Danièle Cybulskie, "The Astrolabe: Medieval Multi-Tool of Navigation" (2015), available at www.medievalists.net/2015/05/the-astrolabe-medieval-multi-tool-of-navigation/ (accessed 2017).

20 https://beforenewton.blog/2017/02/16/the-astrolabe/.

21 http://americanhistory.si.edu/collections/search/object/nmah_214167.

Videos

The blurb on TED.com to introduce Tom Wujec's fine presentation of the use of an astrolabe,[22] mentioned in Part I, reads:

> "With thousands of uses, from telling time to mapping the night sky, this old tech reminds us that the ancient can be as brilliant as the brand-new."

"Mapping the night sky"? This has already been done for you: the rete is a map of the night sky. Nobody ever mapped the night sky with an astrolabe. It is not recommended.

A video recorded for a Malaysian TV station features the historian of astronomy Dr. Rob van Gent and confirms that an informed scholar can hardly share his knowledge whilst being bombarded with uninformed questions.[23] This is especially the case when the interviewer has no idea what an astrolabe is; she gets the discussion off to a bad start by reading aloud the first paragraph of the *Wikipedia* "astrolabe" article.

Emily Winterburn's discussion of the astrolabe on Muslim.Heritage, mentioned in Part I, is well thought out and mainly adequate although the many illustrations need better captions and the section on horoscopes is misleading (because one can not draw up a horoscope with nothing but an astrolabe). Also for a website of this kind the opportunity to explain how many Islamic astrolabes can be used to find the times of all five daily prayers was lost.

A video of myself talking about the astrolabe was made by Muslim Heritage at a university in one of the Emirates some 10 years ago but the video was also lost.

Using an astrolabe

Rob Ossian's "Pirate Cove" site has an entry on the astrolabe, with a mention of how to use one:[24]

> "Astrolabes are used to show how the sky looks at a specific place at a given time. This is done by drawing the sky on the face of the astrolabe and marking it so positions in the sky are easy to find. To use an

---

22 www.ted.com/talks/tom_wujec_demos_the_13th_century_astrolabe..

23 "Astrolabe - its history and application" (2015), at https://www.youtube.com/watch?v=R_xP-SRdebk (accessed 2017).

24 Rob Ossian, "Astrolabe", at http://www.thepirateking.com/historical/astrolabe.htm (accessed 2017).

astrolabe, you adjust the moveable components to a specific date and time. Once set, the entire sky, both visible and invisible, is represented on the face of the instrument. This allows a great many astronomical problems to be solved in a very visual way."

Now there is much to be said for this account for at least it is original and honest and it is correct. Unfortunately it is followed by some misinformation from the *Wikipedia* "Astrolabe" article, and a quick but reasonable overview of astrolabe history, considerably more than most pirates would venture.

Not even professors master the use of the astrolabe. Richard Covington interviewed one for *Aramco World* in 2007:[25]

> ""See that light?" the professor asks, pointing to a ceiling fixture. "Hold the astrolabe up to the light, look along the pivoting ruler on the back and line it up with the light, which is your star," he explains. "Where the ruler crosses a scale that circles the back rim of the instrument, the number shows the altitude, in degrees, of that star above the horizon. You take that measurement and the sun's celestial longitude, using the separate calendar scale on the back, match them up with the star's altitude and the sun's coordinates on the front of the astrolabe, and you can determine the name of the star and its location.""

Again the mind boggles.

Brother William (Sean Connery) held up an astrolabe toward the moon in "The Name of the Rose". This was not a good idea. Looking at planets is also not calculated to achieve much because if you measure the altitude of a planet there is not much you can do with that information. Neither the moon nor the planets are marked on the rete. That's the way it is.

In an article published in an English newspaper in Turkey in 2016,[26] we read:

> " ... . The astrolabe has many uses, including allowing people to identify and/or predict the position of the sun, the moon, the planets and stars. It is possible to use the astrolabe to determine the time or the time in another latitude (or if you know the time, but do not know in which

---

[25] Richard Covington, "The Astrolabe: a user's guide" (2007), at http://archive.aramcoworld.com/issue/200703/the.astrolabe.a.user.s.guide.htm (accessed 2017).

[26] Jane Louise Kadour, "Astrolabe: the 13th Century iPhone" (2015), at https://electronics.howstuffworks.com/gadgets/clocks-watches/astrolabe4.htm (accessed 2017).

latitude you happen to be [!], you can find this out using an astrolabe). ... ."

These remarks show a basic misunderstanding of the way in which time was reckoned in medieval times, as well as of the way in which people wasted their time between different latitudes. Why would a hapless medieval want to know the time in other latitude? He might want to know it in a different locality, but that is another matter.

In a webpage on Islamic astronomy on the site "Explorable - Think outside the box" we read:[27]

> "The astrolabe, used for measuring latitude, was invented by the Greeks, but the Islamic astronomers refined the equipment, improving the accuracy and building beautiful, elegant instruments. Unlike the Greek predecessors, Islamic astrolabes were independent of latitude and incorporated complex gearing mechanisms to track celestial bodies."

Astrolabe used for measuring latitude? Astrolabes independent of latitude? Astrolabes incorporating complex gearing mechanisms? Just one Islamic astrolabe with a luni-solar gear mechanism has survived. The same author continues:[28]

> "Although there is a lot of debate about who built the first astrolabe, the consensus is that Hipparchus has that honor, using it as a much more accurate way of measuring latitude than a gnomon. The astrolabe is an instrument that allows observers to measure the position of celestial bodies relative to the horizon, which allows accurate star mapping. The utility of the instrument does not end there, because it can be used to measure latitude, give the local time and estimate the height of objects; astrolabes were used by surveyors for measuring distance through triangulation. The standard astrolabe consists of a disc with a rotating arm complete with sights, but quadrants, sextants and inclinometers all use the same principle."

Hipparchus preferred to use an astrolabe over a gnomon to measure his latitude? An astrolabe allows accurate star mapping? It's time to move on.

---

[27] Martyn Shuttleworth, "Islamic Astronomy - Precision and Observation: Refining the Works of Ptolemy" (2010) at https://explorable.com/islamic-astronomy (accessed 2017).

[28] *Idem* at https://explorable.com/build-an-astrolabe.

Modern astronomers have a look at the astrolabe

A description of the astrolabe published by an astronomer at the Institute for Astronomy at the University of Hawaii in 2003[29] informs us:

> "An astrolabe is a two-dimensional model of the celestial sphere. ... (It) is an instrument that once was the most used, multipurpose astronomical instrument. Historically, astrolabes were elaborately inscribed brass discs. The portability and usefulness of an astrolabe made it something like the multipurpose "lap-top computer" of our predecessors. With an astrolabe, an astronomer could make quite accurate measurements of the following things:
>
> - position of celestial objects;
> - measure the time of the night (or of the day, using it as a mobile sundial [!] or, more accurately by measuring the altitude of the sun);
> - measure the time of the year;
> - compute what part of the sky is visible at any time;
> - determine the altitude of any object over the horizon;
> - determine the current latitude, and
> - determine (very accurately) the NPS orientation."

Now the uses of the astrolabe listed here are not completely unreasonable. But one does not "measure" the position of celestial objects; and normally one has a fair idea of the time of the year. A user would only need to measure his/her own latitude once (most folk would be happy to use a plate with their own locality marked on it). Further, we are witness here to the way the idea of **the astrolabe only being usable at night** comes from. Using the astrolabe as "a mobile sundial" sounds crazy but, as mentioned in Part I such a sundial device was conceived by the Greeks and survives on some early Islamic astrolabes. This information is irrelevant here.

I do not understand how one can "determine (very accurately) the NPS orientation", because I do not know what NPS stands for. If it stands for "North Pole Star" then we have a problem because this NPS is not actually situated at the celestial pole (this was known, for example, to medieval Arab navigators!), and the pointer for the NPS on an astrolabe rete is the most sensitive pointer (or marker on the central ring), and the one most

---

[29] Karen Meech, "Astrolabes," Institute for Astronomy, University of Hawaii (updated 2003), available at http://www.ifa.hawaii.edu/tops/astlabe.html (accessed 2017).

prone to error. Also Honolulu has a latitude similar to that of Mecca, so the NPS is fairly low on the horizon. On the other hand, NPS may stand for "National Park Service". and Hawaii is full of national parks and maybe an astrolabe would be useful to find one's way to, around, and out of any of these. And this NPS does offer Astronomy programmes.

In *Cosmos – Study Astronomy Online Encyclopedia of Astronomy*, put out by Swinburne University of Technology in Australia, we read in the entry "Astrolabe" stuff that could hardly have been first penned by an astronomer:[30]

> "Astrolabes could only show one hemisphere of the night sky [rubbish!], with the north celestial pole corresponding to the centre of the mater. The night sky (i.e. circles of altitude) [?] were then projected onto the disk [?], with the outer edge of the mater corresponding to the limiting declination of the device. The rete was used to locate [?] the ecliptic – the path of the Sun through the sky, and the location of several prominent stars. Once the altitude of a star was determined (using the alidade), the rete was rotated until the star was aligned with the correct 'circle' of altitude. The centre of the rete was off-axis, to allow for the different stars that appeared throughout the year. As an observer moved to different latitudes, the actual spherical projection required to map the night sky to a flat disk changed [?]. Rather than limiting an astrolabe to a single observing location, interchangeable disks were manufactured: called climates. The observer would choose the climate suitable for their latitude, and the measured altitudes of stars would be consistent with the coordinate lines engraved on the astrolabe [?]."

The mind boggles. But astrolabes have never been made down under. The night sky is also the day sky. Several websites state that an astrolabe can only be used by day, I guess because the sun does not seem to appear on the rete and folk don't know about the ecliptic.

Even the website of the august Smithsonian Institution has recently published a ridiculous article on the astrolabe in which the splendid astrolabe collection of the Smithsonian's National Museum of American

---

30 Anonymous, article "Astrolabe" in http://astronomy.swin.edu.au/cosmos/A/Astrolabe (accessed 2017).

History is not even mentioned.[31] The author cunningly confuses the astrolabe with the mariner's astrolabe, so that it can be used at sea. "Astrolabes had blended uses, from scientific to what we would today consider spiritual", referring to the Muslim requirements of five daily prayers towards Mecca, and Christian European decisions from "when to go to battle to how to go about bank dealings". The author had no idea what an astrolabe is, or what it does, but she was happy to suggest to innocent readers that it was a precursor of the Smartphone. Alas, she cannot claim that her article serves the Smithsonian Institution's noble mission to serve "the increase and diffusion of knowledge".[32]

Writing about Benjamin Franklin in the early 18th century colonial America, Carla J. Mulford, again in the Smithsonian magazine now in 2017,[33] wrote:

> "Accurate instruments, such as the astrolabe, allowed people to measure the motion of the planets and thus predict movements in the heavens, particularly phenomena like solar and lunar eclipses and the motions of planets like Venus."

This curious information was certainly not taken from the Smithsonian's astrolabe catalogue.

German and French absurdities on the astrolabe

Not only in English do we find such fake news about the astrolabe. Dr. Hans-Peter von Peschke, in a German book on the Middle Ages for children,[34] presented a picture of an 11th-century Andalusî astrolabe from the rich collection of the Germanisches Nationalmuseum in Nuremberg, which I actually catalogued over 25 years ago, with the following absurd caption:

---

31 Laura Poppick, "The Story of the Astrolabe, the Original Smartphone – Prosperous times likely paved the way for this multifunctional device, conceptual ancestor to the iPhone 7", http://www.smithsonianmag.com/innovation/astrolabe-original-smartphone-180961981/. The collection was diligently catalogued by Sharon Gibbs and George Saliba in 1984.

32 Ironically, it was the Smithsonian Institution which during 1972-79 generously sponsored the research in Cairo on the history of Islamic astronomy. On that research my present expertise, for what it is worth, is based. The 7-year project was organized by Prof. Owen Gingerich, mentioned in Part I.

33 Carla J. Mulford, "Benjamin Franklin mocked eclipse astrology to elevate science", at http://www.smithsonianmag.com/science-nature/benjamin-franklin-mocked-eclipse-astrology-elevate-science-180964453/ (2017).

34 Hans-Peter von Peschke, *Mittelalter*, Nuremberg, 2004, p. 45.

> "Mit dem Astrolabium (11. Jh.) konnte man den Sonnenstand bestimmen [!] und bei Nacht [!] die Zeit messen, was die Orientierung auf See sehr erleichterte [!]." / "With the astrolabe (11th century) one could determine the position [?] of the sun and at night [!] measure the time, which much facilitated orientation [*i.e.* , finding one's way] at sea [!]."

This rubbish is the more sad because some of the best writings on the astrolabe are in German. Not only the catalogues of the principal collections in Germany, namely, Nuremberg and Munich, provide reliable overviews, but once there was also a German translation of the Greenwich booklet available at the Deutsches Museum. As already noted, the Wikipedia article "Astrolabium" is acceptable, unlike those in other languages.

An anonymous French site labelled "Repérage terrestre – Savoir où nous sommes pour savoir où l'on va" / "Terrestrial tracking – To know where we are and where we are going" has the following information for us:[35]

> "Cet instrument, conçu dans l'Antiquité, permet de mesurer la hauteur d'un astre au-dessus de l'horizon et de déterminer rapidement la position de la Lune, du Soleil ou n'importe quelle planète par rapport aux étoiles. // "This instrument , conceived in Antiquity, enables one to measure the altitude of a celestial body above the horizon and to determine quickly the position of the moon, the sun, or any (old) planet relative to the stars.

This is brilliant start, and it gets better. You hold the astrolabe up with the alidade pointing towards the sun or any star and ...

> On lit alors les degrés sur le disque et il ne reste plus qu'à les convertir en degrés de latitude. // One then reads off the degrees (of altitude) and there is nothing more to do than to convert them to degrees of latitude.

Such an operation, if conducted successfully, would merit a *Légion d'honneur*. In conclusion,

> L'usage de l'astrolabe a été très répandu par les astronomes arabes dès le VIIème siècle [!]. Il servait principalement pour l'astrologie, l'enseignement de l'astronomie et le calcul d'heure. Mais jusqu'à l'invention du sextant au XVIIIème siècle, l'astrolabe fut le principal outil de navigation." // The astrolabe was widely used by Arab

---

35 http://reperageterrestre.e-monsite.com/pages/l-astrolabe-et-le-sextant-les-astres-comme-repere.html

> astronomers starting in the 7th century [actually the 8th, but *ma'lesh*]. It served principally astrology, teaching astronomy, and finding the time. But until the invention of the sextant in the 18th century the astrolabe was the principal tool of navigation."

Oh dear! Finding the time of day or night, astronomy education, and astrology would be more appropriate. But the author is so confused that he also mixes up two different instruments. Why not just look up a French site compiled by people who know what an astrolabe is and how it works, such as that of the association called Méridienne at Nantes?[36] What is particularly sad is that one of the very best books on the astrolabe from a historical and a technical point of view is the *Traité de l'astrolabe* by the Belgian engineer Henri Michel. It was published some 70 years ago, but it contains all that most folk need to know.[37]

The following new information is provided by Abby Cessna, an author for universetoday.com:[38]

> "The astrolabe is a predecessor of the sundial, which is still common today as an ornament in many gardens."

Oy weh! Nobody will be more surprised at this than the many lovers of sundials, who know that the sundial has its own history, stretching back to Antiquity.

William Harris has contributed information on the subject "How Astrolabes Work" to a site howstuffworks.com.[39] His distinction between two types is cute, his descriptions absurd:

> "Planispheric or Maritime, Madam? Zip back to the ancient world and you'd encounter two basic types of astrolabes. The first type, known as a planispheric astrolabe, helped astronomers calculate the positions of celestial objects [!]. All early astrolabes were of the planispheric sort until seafaring folks saw how useful the instruments could be [?].
>
> By about the 15th century, maritime astrolabes began appearing. They were like hacked versions [!] of their planispheric cousins [!], used primarily to determine the altitude of the sun or a star, which could then be used to determine latitude. They came with two basic parts – a

---

36 http://www.meridienne.org/index.php?page=astrolabe.presentation

37 Michel, *Traité de l'astrolabe*, Paris, 1947, translated on Jim Morrison's site.

38 Abby Cessna, "Astrolabe", at https://www.universetoday.com/41624/astrolabe/ (2009/2016), accessed 2017.

39 https://electronics.howstuffworks.com/gadgets/clocks-watches/astrolabe1.htm.

graduated circle and an alidade, a sighting device or pointer used to measure angles. Planispheric astrolabes were a bit more complicated. They were also more idiosyncratic because their operation depended on the user's latitude."

I just love the last two sentences.

Very flat astrolabes

A potentially useful video on the astrolabe presented by one "Brother Abu Ismael" is somewhat compromised by the author's association with a Muslim "Flat Earth" group.[40] Abu Ismael overlooks, amongst other things, the geodetic measurements commissioned by the early-9th-century Caliph al-Ma'mûn, whose purpose was not to establish whether or not the Earth was flat, but rather to derive a value for its circumference more accurate than that derived by the Greeks.

The video presentation entitled "Astrolabe explained" by one "Truth Pion" (2017) is well informed on the astrolabe and planetary astronomy in general, if related in a somewhat unexciting fashion.[41] But it turns out at the end that this too is a "Flat Earth" production.

The universal astrolabe / The universal plate

A researcher Nimira Dewji, devotee of the Aga Khan, has recently written on the astrolabe:[42]

> "... the astrolabe is an ancient astronomical instrument used for observing planetary movements. Astrolabes are amongst the most sophisticated scientific instruments ever made."

"Planetary movements"? How can you measure the movements of the planets with such a device? Yet more charming is what she has written on al-Zarqâllu and his universal plate:

> "Ibrahim al-Zarqali (d. 1987 [*sic*, read 1087]), known as Azarch[i]el in the West, introduced a universal plate capable of calculations at any latitude, thereby rendering the astrolabe usable in any part of the world – it did not need electricity, batteries or WiFi!"

---

40 Abu Ismael, "Astrolabe proves flat Earth" (2017), at https://www.youtube.com/watch?v=AgmO2iF1z2E (accessed 2017).

41 https://www.youtube.com/watch?v=763Yj4JIe9s

42 Nimira Dewji, "Astrolabe, one of His Highness the Aga Khan's favorite artifacts at the Museum", https://ismailimail.wordpress.com/2014/12/22/astrolabe-one-of-his-highness-the-aga-khans-favorite-artifacts-at-the-museum/ (2014).

So be it.

A heliocentric astrolabe

It was inevitable that the *zawraqî* or "boat" astrolabe should confuse modern writers. The celebrated Iranian historian of Islamic philosophy Seyyed Hossein Nasr in his 1968 *Science and civilisation in Islam* declared that al-Sijzî (Iran, *ca*. 1000):

> "was particularly noted for constructing an astrolabe based on the notion of the earth around the sun."

Here we see total confusion.[43] Fortunately this assertion does not appear to have been repeated left, right and centre in the more modern literature. But in Nasr's defence we should mention that al-Bîrûnî's discussion of this astrolabe does occur in the middle of a discussion of Muslim statements about heliocentricity, such as would have made Copernicus jump.

The mariner's "astrolabe"

This device is not an astrolabe in the sense that it serves only one simply function, measuring solar or stellar altitude, whereas the astrolabe, besides being a model of the universe, is a multi-functional instrument. However, the astrolabe is for landlubbers and the mariner's astrolabe is for mariners, preferably for those who know what to do with the solar altitude once they have measured it. Some folk think mariners only used it a midday. In fact, one can use it to find the time of day, if one has the necessary wits and the appropriate astronomical tables.

The author of the *Wikipedia* article on the Mariner's astrolabe is correct in labelling it an inclinometer:[44]

> "The mariner's astrolabe, also called sea astrolabe, was an inclinometer used to determine the latitude of a ship at sea by measuring the sun's noon altitude (declination) or the meridian altitude of a star of known declination. Not an astrolabe proper, the mariner's astrolabe was rather a graduated circle with an alidade used to measure vertical angles. They were designed to allow for their use on boats in rough water and/or in heavy winds, which astrolabes are ill-equipped to handle. In the sixteenth century, the instrument was also called a ring."

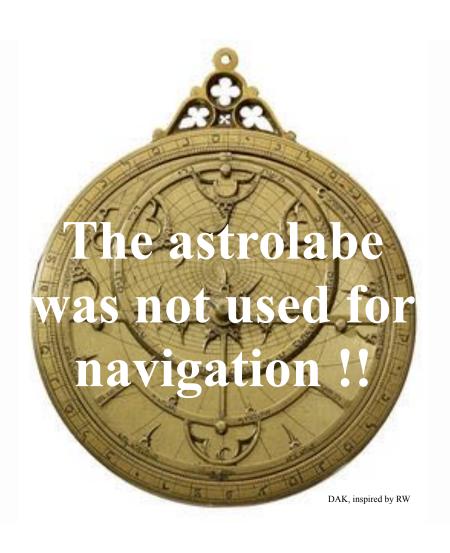
43 Nasr, *Science and civilisation in Islam*, p. 170.

44 https://en.wikipedia.org/wiki/Mariner%27s_astrolabe

The expression "noon altitude (declination)" is misleading, not least because most readers will not know how the meridian altitude is related to the latitude and the solar declination. Here, as elsewhere, there is no discussion of the way one can find the time of day using such an astrolabe. If one could not, there would be no use for the astrolabe if one was travelling due east or due west. People just do not like tables.

A specialist on marine history has written recently about 'real' astrolabes:

> "Astrolabes were widely used for astronomical observations and calculations, **for nautical and land navigation**, for surveying, for time-calculation, and so on."

So there really is no hope that normal people can be expected to know that **real astrolabes were never used for navigation**.

The mariner's "astrolabe" appears out nowhere in the 15th century. It has no known Islamic predecessors. Thus it is rather surprising to read on the website of the Royal Museums, formerly Royal Maritime Museum, Greenwich:[45]

> "The mariner's astrolabe was a simplified version of an instrument originally developed by Arab astronomers for measuring the height of heavenly bodies above the horizon and came into use in navigation by about 1470."

Arab astronomers did not generally go to sea and they did not develop any mariner's astrolabe.

The American historian Patricia Seed, in a recent article about celestial navigation, has written:[46]

> "(The standard astrolabe) required massive revision before it could translated into an instrument for navigation."

The steps by which Seed imagines the standard astrolabe was reduced to the mariner's astrolabe need not be repeated here. Alas her imagination has gone completely overboard, for all the instruments really have in common is, by historical accident, a name. Her text also includes some information about Islamic astronomy and mathematics that I never heard before, despite having been working on these disciplines for almost 50 years.

What has been clear for a long time is that the mariner's astrolabe evolved. And just as I was writing these lines we found a missing part of the story. "Astrolabe ... ". Thus began a BBC article today (25.10.2017), as I write this. The word 'astrolabe' is being bandied about again in the press with the rediscovery in 2016 of an astronomical device recovered in the wreck of a Portuguese explorer named Esmeralda, which sank off Oman in 1503.[47] This is a circular bronze plate with a throne and two decorative protruding blazons on one side, which probably serve to counter-balance the now-missing alidade. On the other side traces of a 5° altitude scale have been identified, and the hole at the centre indicates that an alidade was once fitted there.

---

45 Anonymous, "Greenwich (Valentia) astrolabe", at http://collections.rmg.co.uk/collections/objects/42234.html

46 Patricia Seed, "Celestial navigation: The First Translational Science", place?, date?, p. 24.

47 http://www.bbc.com/news/science-environment-41724022 (2017).

Researchers at Warwick, when they found evidence of etchings around the edge of the disc, each separated by 5°, pronounced that this detail "proves it's an astrolabe",[48] because

> "these markings would have helped mariners measure the height of the sun above the horizon at noon – a strategy that helped them *figure out their location* while at sea."

The words in italics lead to another site which could help if a mariner knows only the solar altitude at noon. It is appropriately entitled "Why humans get lost".[49]

This piece is not an astrolabe, of which we have over 1,000 examples with Arabic or Sanskrit or Latin inscriptions. This is not a typical mariner's astrolabe, of which we have over 50 examples. It is, in fact, a unique example of a proto-mariner's astrolabe, before it was realised that the instrument needed to be thicker and heavier to make it more stable on board a ship, with cutouts in the metal to lessen the effects of wind, and with weight adjustments to ensure that it hangs vertically.

A mariner's "astrolabe" is far more useful if one has onboard a table displaying the altitude of the sun at each (seasonal) hour of daylight. One can then measure the solar altitude, even at sea, and find the time of day. One does not need a table for different latitudes because the most serviceable tables were based on an approximate formula that worked reasonably well for all latitudes (at least in the Near East, where it was conceived, if not in Europe, where it was used with abandon for centuries even though it didn't work properly at higher latitudes).

A sober article in *The Economist* of 26.10.2017 is headed "Navigational instruments: The oldest mariner's astrolabe yields to scientific scrutiny – Laser scanning shows how it worked".[50] A curious title, since it is obvious how it worked. As far as I am aware, the function, as opposed to the symbolism, of the two blazons has not been addressed in the press. They do serve a practical purpose.

---

48 Laura Geggel, "It's Official: Earliest Known Marine Astrolabe Found in Shipwreck" (2017) at www.space.com/38561-oldest-astrolabe-navigation-tool-found.html (accessed 2017).

49 Tia Ghose, "Why Humans Get Lost" (2013) at www.livescience.com/27787-why-humans-get-lost.html (accessed 2017)

50 https://www.economist.com/news/science-and-technology/21730625-laser-scanning-shows-how-it-worked-oldest-mariners-astrolabe-yields (accessed 2017).

On an educational site owlcation.com we find the history of the mariner's astrolabe "invented 2000 years ago" as "an instrument of navigation used to measure celestial altitude".[51] The potted history of the instrument that follows relates however to the standard astrolabe, a different instrument altogether.

One might welcome a new project to document all surviving mariner's astrolabes, announced in 2015.[52] However, the organizers get off to a bad start by calling their undertaking "The Astrolabe Project", and they trip over at the starting line:

> "Marine astrolabes were a simplification of the existing Islamic calculating devices and were used during the sixteenth and seventeenth centuries to measure the height of the sun at noon on sailing ships. With this value and the proper tables, sea captains could calculate the latitude and estimate the position of their ships during the long oceanic voyages that characterized the first age of globalization."

The first half of the first sentence of this abstract is utter rubbish. With the right kind of tables, universal for all reasonable latitudes, one can measure the solar altitude at any time of day and read off the hours since sunrise or remaining to sunset. Now which instrument are we talking about?

> "Originally developed in Roman Egypt, later adapted by Islamic scholars, and passed into the neighboring Iberian states, astrolabes are part of an intellectual revolution that gave the world larger and sturdier ships and a sophisticated bureaucratic organization. The Portuguese and Spanish early modern states planned and implemented imperialist policies on a theater that encompassed a large portion of the known world. Astrolabes helped fifteenth and sixteenth century sailors find their way around the planet and allowed geographers and cosmographers to create the maps from which the Catholic, Protestant, and Islamic rulers planned their strategies and wars. Their form and style reflect the knowledge, skills, and taste of their makers and are a product of the cultural and economic environment within which they were cast."

Wow! Astrolabes gave the world larger and sturdier ships and a sophisticated bureaucratic organization. *Mâshâ'allâh*!

---

51 Teresa Coppens, "The Astrolabe: How to make one and understanding its use" (2016), at https://owlcation.com/stem/History-of-the-Astrolabe-and-How-to-Make-One (accessed 2017).

52 Castro & Budsberg & Jobling & Passen, "The Astrolabe Project" (2015).

From no other source than NASA we have the following nonsense,[53] making one wonder how they navigate through space:

> "In particular, navigators used and improved upon [!] the early astrolabe and cross staff, two devices created in ancient times to measure the altitudes of celestial bodies. These devices enabled sailors to travel in an east-west direction [!] away from the sight of land. The astrolabe was a simple sphere [!!] made of brass, measuring about six inches in diameter. ... ."

Travel possible only in san east-west direction? The astrolabe a sphere? This really takes the biscuit, as they say.

As we have seen throughout Part II, various other websites confuse the astrolabe and mariner's astrolabe altogether, some presenting absurd historical overviews of both at the same time.[54]

New potted histories of the astrolabe

Karen Carr has a doctorate in Classical Art and Archaeology and is a retired professor of Department of History at Portland State University. She maintains a kind of blog named Quatr.us Study Guides (more than 2500 original articles on everything from Aachen to zygotes). She presents the following charming answer to the question "What is an astrolabe?":[55]

> "About 140 BC, the Greek astronomer Hipparchus of Rhodes invented the science of trigonometry. Hipparchus figured out that you could use an imaginary right triangle whose corners were the sun, the earth, and the planets or stars, to calculate the movements of the planets and stars. To measure the angles of these right triangles accurately, Hipparchus invented a metal tool called an astrolabe. It's a kind of analog calculator, like a slide rule.
>
> "Later West Asian scientists, first Greek, then Christian, then Muslim, made gradual improvements to the astrolabe over the next thousand years. Islamic astronomers added markings so that you could find how far away from due north you were.

---

53 https://www.nasa.gov/topics/universe/features/zombie-stars-sidebar.html

54 Anonymous, "Astrolabe" (2017), at exploration.marinersmuseum.org/object/astrolabe/(for children).

55 Karen Carr, "What is an astrolabe. Greek science" (2017), at https://quatr.us/greeks/what-is-an-astrolabe-greek-science.htm (accessed 2017).

> "In the late Middle Ages, Chinese scientists shared the idea of making a magnetic compass with Islamic astronomers and from there the news spread to Europe. Then sailors – or at least highly skilled navigators – were able to combine the use of the astrolabe with the use of the compass to figure out where they were on the ocean when they couldn't see the land."

The text is illustrated with an astrolabe for which the caption reads: "An Islamic astrolabe (832 AD)". The illustration inevitably shows the infamous undated Florence astrolabe from Abbasid – 10th-century – Baghdad which we discussed in Part I.

This response should never have been written, and woe to anyone who would believe one word of it. Hipparchus' right triangles are not at all alright and he did not invent the astrolabe. The millennia are confused. The Christians before the Muslims were Greek. Muslim astronomers did not learn of the magnetic compass from the Chinese. The account of the astounding achievement of the Muslim scholars in adding markings to find how far away from due north one is, is curious indeed and unworthy even of an art historian. The European Middle Ages have vanished, and so has the Renaissance. And so will sailors who cannot use an astrolabe and a compass.

We now turn to an anonymous article at a would-be educational site "History 27012 Wiki" which is entitled "Islamic astrolabe discovered in Spain".[56] The astrolabe featured and illustrated actually has inscriptions in Hebrew, but *ma'lêsh*, this is not the only problem. The instrument is supposedly dated 1345-1355 CE, but, as we shall see, much of the information on the history and development of the astrolabe is unreliable. This is particularly strange since it gives the impression of being based on half a dozen scholarly writings on the history of the astrolabe, including one of my own (an encyclopaedia entry listed under Selin).

The following quotes, no longer in order, are perhaps worth recording here:

> "The astrolabe is an ancient astronomical tool used to measure the position of the sun and the stars as well as solve problems of time. Inventors of the astrolabe re-created the sky on the face of the instrument and marked it so that celestial bodies were easy to find.

---

56 Anonymous, "Islamic astrolabe discovered in Spain", at http://history2701.wikia.com/wiki/Islamic_Astrolabe_Discovered_in_Spain(accessed 2017).

> " ... ... The plates, commonly called climates, are inserted into the mater and are engraved with circles of altitude and lines [!] of latitude [!]. ...
>
> "During the Dark Ages, many Greek astrolabes [!] and manuscripts were lost, specifically in the burning of the library in Alexandria, Egypt. This coupled with the sequestering of knowledge by the Church resulted in the loss of astronomical knowledge in the Western world. However, from 12 AD [?] to the 12th century [?], astrolabes were re-introduced [?] to the Western world as Islamic astronomers sought out and uncovered the remaining Greek astrolabes [!] and manuscripts. They expanded on the uses and technology of astrolabes and disseminated this knowledge as Islam was spreading throughout North Africa and southern Europe. ...
>
> "Dating back to 1345-1355 C.E., this astrolabe is made of brass and was found [?] in Spain, where it [?] was introduced by Islamic astronomers after the Muslim conquest of the Iberian Peninsula in the 8th century ... . Muslims used astrolabes to find the times of the sunrise [!] and the rising of fixed stars and to help schedule morning prayers [?] facing Mecca.
>
> " ... Islamic astronomers primarily used the astrolabe to develop a calendar of astronomical events important to the Islamic faith, determine exact moments of sunrise and sunset for prayer times, and position mosques and direction of prayer toward Mecca. ... "
>
> "By the 16th century, the astrolabe was a basic educational tool in mathematics and astronomy. It was largely replaced by the invention of the telescope [!], but those who were able to employ an astrolabe were considered educated and well-schooled. As for time-keeping, the pendulum clock and the chronometer replaced the astrolabe, making it a thing of the past. However, the workmanship behind beautiful astrolabes was evidence of the advancements of technology in metalwork.

A charming short history of the astrolabe was put on-line in 2008 by Rhiannon, "a self proclaimed museum junky, who spends her free time doodeling [?], curling up with a good book, or contemplating the meaning of the universe".[57] She admits that this is "a pint-sized wealth of useless information", but claims that her main source is the *Encyclopaedia Britannica*. Rhiannon writes:

> "Throughout the ages all cultures have had some sort of fascination with the sky and/or the celestial bodies. As this fascination grew people began

[57] Rhiannon, "The Astrolabe: World's Oldest Scientific Instrument" (2008), at http://vaultsofhistory.blogspot.de/2008/10/astrolabe-worlds-oldest-scientific_20.html

> to develop astronomical tools to help them study the sun, moon, stars, and other planets. The astrolabe, often referred to as the oldest scientific instrument in the world, has been used to measure/predict the location, height, and position of extraterrestrial bodies, to determine the time of day, and to navigate ships.
>
> "Around the 2nd century BC the astrolabe was developed in ancient Greece to determine the altitude of objects in space. However the instructions for this tool's construction were supposedly lost in the fire at the Library in Alexandria [!]. During the approaching Dark Ages astronomical information was further lost to the western world as the Christian churches banned such knowledge. The preservation of astrolabe technology is credited to the Islamic cultures, as they collected as many remaining Greek astrolabes as possible, thus preserving and improving the uses of the astrolabe. In 12 AD [!], as Islam migrated though southern Europe, the astrolabe was reintroduced [!] to Western World."

Somehow in 2012 we were not called upon to celebrate 2,000 years of Islamic civilization. But numbers, unlike words, do not lie, and the date 12 CE was also mentioned in the previous site above. It does not appear to have been taken from the *Encyclopaedia Britannica*. Where it comes from *Allâhu a'lam*.

Proof that leading scientists even in the early 17th century still used astrolabes is perhaps provided by the following story, for whose authenticity I cannot vouch. The story supposedly concerns John Keill (1671-1721), the Scottish mathematician and disciple of Isaac Newton, whilst at Oxford. He apparently preferred "the conviviality of jolly and learned Gownsmen" in a local tavern to "the confines of the Senior Common Room". Whilst staggering home after "relaxing and refreshing draughts from pots of ale", he collapsed into a ditch by the Rotunda. "Thereupon he whipped out his Astrolabe with intent to obtain a fix on the fading moon, but finding the heavens whirling above him, fell senseless into a drunken stupor." At daybreak, he was discovered by two Proctors who carried him to safety in his own chambers. All's well that ends well.

Museums beyond hope

It is a fact of life that a potsherd has a better chance than an astrolabe of being appropriately displayed and described in most museums. What has happened to certain historically-important astrolabes in their present

domiciles is a disgrace. In this and the subsequent sub-section I give some examples.

In 2016, I was approached by an art-historian colleague from a museum in Ingelheim near Mainz for help in obtaining an astrolabe for an upcoming general historical exhibition. I told her that to liberate an astrolabe quickly from any museum locally would be difficult. But I could offer two modern astrolabe copies: one of a 10th-century Iraqi astrolabe given to me by my colleague Prof. Fuat Sezgin, and the other a model of a 16th-century German astrolabe actually made in Ingelheim and presented to me by a former instrument seminar participant. My condition for lending them was that they should display a text which I had written. The label that actually appeared in the show-case was quite different:

> "The astrolabe, an instrument for measuring angles, was developed already in Antiquity. With it one can aim at a celestial body and measure its altitude in angular degrees. The oldest known European astrolabe is a copy of an Islamic one from Moorish Spain. The astrolabe is a two-dimensional model of the heavens, as seen from a particular latitude."

Again, here we go:

- The astrolabe is not an instrument for measuring angles. Such a device is called a protractor.
- Having measured the altitude of a 'celestial body' – why not say the sun or any bright star – what does one do with the result?
- The oldest known European astrolabe, from 10th-century Catalonia, is not a copy of anything Islamic. Not does it resemble any other medieval European astrolabe. It is so 'different' that it was declared a fake by scholars with no experience with actual astrolabes. It has now been reinstated to its rightful position (see below).
- 'The heavens' is problematic here. It makes more sense to think of an imaginary celestial sphere of arbitrary radius, centred on the observer.

Even when an astrolabe collection has been catalogued, we can find people innocent of what an astrolabe is being called upon to describe what it is. Thus, for example, we find our favourite Judaeo-Arabic astrolabe featured as an instrument "used to make astronomical measurements and in navigation".[58]

---

[58] Nasser D. Khalili, *Visions of splendour in Islamic art and culture*, London, 2008, p. 120.

I now mention four astrolabes which have suffered at the hands of the museums that house them.

(1) The most exquisite astrolabe of the early period of Islamic instrumentation, that of the 10th-century astronomer al-Khujandî, was offered to the Oxford Museum of History of Science in 1929 by a dealer in London. The curator, Gunther himself, consulted the leading Arabist in Oxford, who misread the date as 778 Hijra [= 1376], The vendor had considered it much older, having read the date as 378 Hijra [= 960], but:

> "to judge from the appearance of the metal, the instrument is not of such antiquity".

With these words, Oxford lost this spectacular piece.[59] Half a century later the instrument was acquired by a Paris dealer and eventually sold to a Kuwaiti collector, who was keen to have it properly documented, and then to the new Museum of Islamic Art in Doha, for whom an astrolabe is "a medieval scientific instrument used for astronomical calculations and navigation". The Museum has nothing of consequence on this astrolabe on its website, and no bibliography. And none of the websites devoted to al-Khujandî makes any mention of it. Sad!

(2) Once a historical instrument has been branded as fake or suspicious by folk who do not understand it, it is never possible to fully reinstate it. One good example is the Destombes astrolabe, the earliest known European astrolabe, the vicissitudes of whose struggle have been related above. Now that it has been restored to its rightful place in history, the Institut du Monde Arabe in Paris, where it is housed, seems to have forgotten about it. Perhaps this is because it is not "Arab" but more probably because "some people" used to say it was a fake. Their bookstore has neither anything sensible on the Destombes astrolabe nor the catalogue of their rich collection of Islamic astrolabes, but it does offer a new novel for children entitled *Le secret de l'astrolabe* and with a fake or imaginary astrolabe on the cover.

On a different level, we have an overenthusiastic *Wikipedia* article "Barcelona astrolabe" which in an amateurish way associates the instrument directly with the city of Barcelona and a new, fictitious "engraved" date of 980, and more ... .[60]

---

59 Gunther, *Astrolabes*, I, p. 245 (#111).

60 https://en.wikipedia.org/wiki/Barcelona_astrolabe.

(3) In 2005 I published an astrolabe preserved in the Cairo Museum of Islamic Art in Cairo in a chapter entitled "Some astronomical instruments from Medieval Syria". This was an unsigned, undated piece on which the astronomical parameters used on the plates – latitude for Damascus and obliquity of the ecliptic – can be uniquely associated with the early-14th-century Damascus astronomer al-Mizzî. In the light of various minor defects – orthography of some star-names – the astrolabe cannot be by the master himself (compare his splendid quadrant in the British Museum), so I have attributed this fine Mamluk Syrian astrolabe to one of his students.[61]

Now the piece is on display at the new(ish) Biblioteca Alexandrina and is featured on its website.[62] It is happily assigned to the "Ottoman era (1517-1922)" without location. Its function is fancifully summarized as follows:

> "The astrolabe is a precise astronomical instrument to measure the location of the sun, planets and some stars in the hemisphere. It measures angles, shape, size and height as well as the course of celestial objects around the celestial. The astrolabe is used to solve many astronomical issues. It played a big role in the navigation of military and commercial ships. It was also used to calculate time night and day, while Muslim astronomers used it to determine prayer time, the direction of the Qibla and the eclipses of the sun and the moon."

There is no description of any part of this particular astrolabe, which is of primary historical importance, but a few general remarks on the instrument are presented, including that:

- the universal astrolabe of al-Zarqâlî "can be used from anywhere on earth (!)";
- that Ibn al-Shâtir invented the first astrolabic clock called *al-basseet* to determine prayer time(s), thereby confusing his magnificent sundial (*basîta*) on the minaret of the Umayyad Mosque with the astronomical clock he had in his garden; and
- "Ahmed ibn al-Sarrâg" developed an astrolabe "which combined all the advantages of previous inventions".

The dialectal orthography of the name of Ibn al-Sarrâj confirms that the author was an Egyptian. Ibn al-Sarrâj, on the other hand, was from Aleppo.

---

61 King, *Synchrony*, XIVb: 705-709.

62 Anonymous, undated, article "astrolabe", at http://antiquities.bibalex.org/Collection/Detail.aspx?a=949&lang=en (accessed 2017).

(4) The remarkable astrolabe recently acquired by the Aga Khan Museum in Toronto is perhaps the most historically important medieval European astrolabe. It is an elegant 14th-century quatrefoil astrolabe, most probably made in Toledo. It bears the latitudes scratched on each of the plates in Hebrew, clearly maker's marks, then most of the inscriptions are in Latin, with a later overlay of inscriptions in Arabic showing that it was acquired by a Muslim intent on taking it to Algiers. We read on the Museum webpage:[63]

> "Planispheric astrolabe, from the Iberian peninsula, 1300s. ... The inscriptions on the astrolabe bear the names of constellations [!] in both Arabic and Latin, with additional inscriptions in Arabic [?]. Later [!], Hebrew was added to one [!] of the plates."

Another problem is that this piece has been associated with Toledo, for lack of any feasible alternative. There are no names of any constellations on astrolabes; the author means 'zodiacal signs'. Who cares? There is no hint of the fact that this astrolabe has been published in the greatest detail in a monograph accessible on the internet.[64]

Now if the latitudes on every plate scratched in Hebrew characters, normally out of sight since they are hidden by the rim of the rete, were made by the maker, then he was a Jewish craftsman. If, as is now claimed, the Hebrew scratches were added later, after the Latin and Arabic inscriptions, then they are entirely superfluous because the latitudes in Hindu-Arabic numerals would have been already engraved, properly at that. The Museum now makes the Hebrew inscriptions last, which distorts the delicate history of this monument to *convivencia*.

None of the other exciting features of this instrument – such as the earliest attested use of fractions, and the only example of the use of a 'new' letter of the Latin alphabet, to mention just two – are mentioned in the Museum website. The engraving holds the key to the exact provenance of this piece, but that is not to be established by guesswork. Toledo seemed a reasonable choice, the Museum now introduces Saragossa, inevitably without any explanation. The Museum has yet to do justice to its prize possession.

---

[63] Nimira Devi, "Astrolabe, one of His Highness the Aga Khan's favorite artifacts at the Museum" (2014) at https://ismailimail.wordpress.com/2014/12/22/astrolabe-one-of-his-highness-the-aga-khans-favorite-artifacts-at-the-museum/ (accessed 2017)

[64] http://www.ub.edu/arab/suhayl/volums/volum3/paper%201.pdf.

The 2012 novel by Gerhard Behrens entitled *The Toledo Fake*, in which an 11th-century astrolabe sells for £2.8M at auction in London and a few days later an eccentric expert of Islamic art and science is murdered in his modest London flat, and more, has surely attracted more attention than the real Toledo astrolabe. The book is a work of fiction because there is no 11th-century astrolabe from Toledo, no astrolabe ever sold for £2.8M, and there are no British experts on both Islamic art and Islamic science.

The auction houses

In the "good old days" – I think of the 1990s – the major auction houses in London and Paris had consultants who knew what an astrolabe was and who themselves had contributed to the history of the subject. This has certainly changed, for nowadays astrolabes with false descriptions can realise almost six-figure sums (pounds), astrolabes can be auctioned without reference to other known and documented pieces by the same maker, manuscripts of astrolabe-treatises are offered that are incompetent scientifically-erroneous copies, ... Also, it is often clear that the people who write the catalogue descriptions, or the "expert" at Christie's who wrote the blurb:

> "Astrolabes, the beautiful objects that were the 'medieval iPhone ... ."

have but limited understanding of what an astrolabe is, illustrating their accounts with late astrolabes of limited historical interest and a fake astrolabe manuscript.[65] Alas, in general, nobody should any longer trust the information on astrolabes coming from the major auction houses.

Even Sotheby's of London in 2017 prefaced a serious description of an 11th-century Andalusî astrolabe from Córdoba with the following:[66]

> "Astrolabes are elaborate instruments designed to determine the solar or stellar hour at a specific location, allowing the user to make a number of astronomical or astrological observations. They were used by astronomers and navigators from classical antiquity to the Renaissance."

What on earth (or in heaven) is a "stellar hour"? Now we have "astronomical and astrological observations". And then the "navigators" make their customary appearance.

---

65 http://www.christies.com/features/Astrolabes-8196-1.aspx (2015).

66 http://www.sothebys.com/en/news-video/slideshows/2017/the-anatomy-of-an-astrolabe.html#

An astrolabe auctioned at Bonhams of London in 2017 with an incorrect provenance and misdated by 400 years was introduced with the following misinformation:[67]

> "Astrolabes were widely used in the Islamic world both for navigation and for finding the qibla, or the direction of Mecca. They were also used to find the times of sunrise in order to help schedule morning prayers."

But, I need to keep repeating, **astrolabes were not used in the Islamic world for navigation**. Nor were they used for finding the qibla, except in a very few cases. One has to be pretty thick to need to determine the time of sunrise, which is 0 o'clock in medieval Arabic usage. To be sure one can calculate the duration of twilight with an astrolabe, and tables displaying this throughout the year were also available, at least in the major Muslim cities.

The encyclopaedias

The article "Astrolabe" in the *Encyclopædia Britannica* and britannica.com, written by "the editors", is something of a national disgrace.[68] It is very uninspired and is accompanied by an illustration of a ridiculous, totally unrepresentative 16th-century iron astrolabe:

> "Astrolabe, any [?] of a type of early scientific instrument used for reckoning time and for observational purposes. One widely employed variety, the planispheric astrolabe, enabled astronomers to calculate [?] the position of the Sun and prominent stars with respect to both the horizon and the meridian. It provided them with a plane image of the celestial sphere and the principal circles – namely, those representing the ecliptic, celestial equator, and tropics of Cancer and Capricorn. Because of such features, the planispheric astrolabe can be regarded as a kind of rudimentary [!] analogue computer.
>
> "Although astrolabes have been traced to the 6th century [?], they appear to have come into wide use from the early Middle Ages in Europe [first ??] and the Islamic world [second ??]. By about the mid 15th century, astrolabes were adopted [?] by mariners and used in

---

67 "A rare Andalusian brass astrolabe, Islamic Spain, 13th century, probably before 1238", at https://www.bonhams.com/auctions/24197/lot/116/?category=results&length=90&page=1 (accessed 2017).

68 https://www.britannica.com/science/astrolabe-instrument (accessed 2017).

> celestial navigation [?]. The so-called mariner's astrolabe was later supplanted by sextants. ... "

The reader may be forgiven for thinking that the astrolabes in the first sentence of this quote are the same as the astrolabes in the second sentence, which is not the case. And just how, pray, does one calculate the position of the sun and stars? The sloppy reference to the Islamic world after Europe is inappropriate since Europeans were totally indebted to the Muslims for their first contacts with the astrolabe. The only correct information in this quote is that the mariner's astrolabe is a "so-called mariner's astrolabe", for, in fact, it is not an astrolabe at all.

The author of this page has the audacity to state that "the astrolabe can be regarded as a kind of rudimentary analogue computer", whereas there is nothing rudimentary about the astrolabe. It is precisely an analogue computer in the original sense of this expression, of which our author has not learned or understood the rudiments. The corresponding article in the 1911 edition of the *Encyclopædia Britannica* is inevitably better informed.[69]

The article "Astrolabe" in the *Encyclopædia Americana*, surely an old edition, has no inkling about planispheric astrolabes:

> " ... an instrument for measuring the degrees, minutes, and sometimes even the seconds, of angles. It generally consists of a horizontal circular plate of metal, having those divisions on its extreme circumference. The utmost accuracy may be obtained in the measurement of angles, by means of a peculiar contrivance (vernier) ... ... [oops!] ... ."

Oh dear, the author is talking about an instrument completely different from our beloved astrolabe. He/she is talking about the "plain" or "plane table", an instrument used in surveying, not in astronomy. But no, what am I saying? Our author continues – now talking about the sextant without mentioning its name – and concludes by mentioning the first application of the astrolabe to navigation – now we are talking about the mariner's astrolabe – by Martin Behaim of Nuremberg in the 15th century.

Likewise, the article "Astrolabe" in simple.wikipedia.org is pathetic:[70]

> "The astrolabe is a tool using [?] the positions of the stars or sun. It was formerly [?] used in navigation to help explorers and sailors figure out

---

69 https://en.wikisource.org/wiki/1911_Encyclopædia_Britannica/Astrolabe.

70 https://simple.wikipedia.org/wiki/Astrolabe.

> where they were. They found their the distance north and south of the equator by measuring the distance of the sun and stars above the horizon [this would be really clever!]. Astronomers used other kinds of astrolabes, usually larger ones [actually they were mainly smaller!]."

According to the *Collins English Dictionary* (2009), an astrolabe is:

> "An instrument used by early astronomers to measure the altitude of stars and planets and also as a navigational aid. It consists of a graduated circular disc with a movable sighting device."

We read in *The American Heritage Science Dictionary* (2005) that the astrolabe is:

> "An ancient instrument used widely in medieval times by navigators and astronomers to determine latitude, longitude and time of the day. The device employed a disk with 360 degrees marked on its circumference. Users took reading from an indicator that pivoted around the center of the suspended device like the hand of a clock. The astrolabe was replaced by the sextant in the 18th century."

The *Random House Dictionary* (2013) explains an astrolabe as:

> "An astronomical instrument for taking the altitude of the sun or stars and for the solution of other problems in astronomy or navigation; used by Greek astronomers from about 200 B.C. and by Arab astronomers from the Middle Ages until superseded by the sextant."

Clearly things are not improving.

Sometimes the information on the astrolabe is in "new-speak", unintelligible to this author and probably to most readers. The article "Astrolabe" on encyclopedia.com maintains:[71]

> "Astrolabes depict the visual reference points of stars on the night sky as a function of time. As such, an observer can also set the time to predict the visible star pattern expected."

The mind boggles. I just feel sorry for anyone who reads this kind of nonsense.

The new Islamic connection

There is a new study by some Malaysian scholars of the history of the astrolabe in Greek, Islamic and European civilisation, based entirely on

---

71 www.encyclopedia.com/science-and-technology/astronomy-and-space-exploration/astronomy-general/astrolabe (2003), accessed in 2017.

secondary sources. The authors make no reference to surviving instruments, although a few pictures without captions have been added from the internet.[72] Another study deals with the astrolabe as an "astrofiqh instrument", *fiqh* being the Arabic term for Islamic law and referring here to the *qibla* and prayer-times.[73] However, this study omits any reference to the well-documented history of the determination of the qibla and times of prayer by complicated tables and instruments for well over a thousand years and makes no mention of any surviving astrolabes.

A woman astrolabist

Of all the 30-odd Muslim astrolabists from the 8th, 9th and 10th centuries whose names are known to us from the 10th-century Baghdad bibliographer Ibn al-Nadîm,[74] only one has made it into the popular literature, and she is a woman. All that we know of her is that she was called simply al-ʻIjliyya, that she made astrolabes, and that her father, al-ʻIjlî, made astrolabes, and that both of them, father and daughter, were students of the famous instrument specialist of Baghdad, Nastûlus. In addition, she went on to work for the Syrian ruler Sayf al-Dawla, founder of the Emirate of Aleppo. This is not much to go on, but it has been embellished dozens of times and now she is the best-known Muslim astrolabist in the world. For example:[75]

> "Mariam [!] Al-Astrulabi [*sic* for al-Asturlâbî] was a Muslim scientist [?] born in Syria [*sic* for Baghdad] in the (early) 10th century who is famous for developing astrolabes, navigational devices [!!] used to locate and predict the position of the sun, stars *etc* and the determining of latitudes [!] using local time and *vice versa*. ... ... Her genius level intellect [!] made her designs superior to others [?] and the astrolabes designed by her were more intricate [!] and innovative [!] and thus more useful."

---

72 Mohd Hafiz Safiai & Ibnor Azli Ibrahim, "Tracing the history of astrolabe invention across civilisations" (undated, but recent), at http://www.iais.org.my/e/attach/IslamScienceConf/s7_spk2_paper.pdf (accessed 2017),

73 Mohd Hafiz Safiai, *et al.*, The Continuity of astrolabe as a multipurpose *astrofiqh* instrument", *International Journal of Applied Engineering Research* 11:9 (2016): 6081-6086 at https://www.ripublication.com/ijaer16/ijaerv11n9_01.pdf (accessed 2017).

74 King, *Synchrony*, XIIIb: 453-455.

75 One example out of dozens must suffice: Anonymous, "Miriam Al-Astrulabi" (2013), produced by NUST Science Society Blog at https://nustscienceblog.wordpress.com/2013/12/28/mariam-al-astrulabi/ (accessed 2017).

The name Mariam is fictional. The name al-‘Ijliyya has been suppressed probably because readers will not understand it. Surely she bore the epithet al-Asturlâbî, but please spell it right, because astrolabe is *asturlâb* in Arabic. Her greatest claim to fame was that she was a student of Nastûlus. He was, as we have said, the leading instrument-maker in Baghdad *ca*. 900. But his name is strange and was massacred by medieval copyists. It is even more strange to a modern Arab ear. He did not bother to dot the first letter of his name: his signature could be read Nastûlus (one dot above) or Bastûlus (one dot below). So when the first of his astrolabes came to light in the 1970s his name was read as Bastûlus (supposedly related to Greek apostolos, not a good name for a Muslim). It took considerable effort to reinstate the name Nastûlus (related to Nastûrus and the Nestorians). Now he has become established as Bitolus.

Our al-‘Ijliyya has given rise to a trilogy science fiction novellas in an Afrofuturist setting where the main character is from a family that allegedly makes astrolabes, although these are mainly of use in making phone-calls:[76]

> “In Nnedi Okorafor’s Nebula Award-winning novella *Binti*, the eponymous main character is a young woman who is an expert at crafting Astrolabes, a device that was used to discern the position of the stars and planets around us in ancient times, useful for everything from astronomy to time keeping to horoscopes. ... Recently on Twitter, Okorafor cited this woman as an inspiration for her protagonist Binti, saying that she learned of Al-Ijliya at a book festival in the United Arab Emirates. ... Mariam “Al-Astrolabiya” Al-Ijiliya lived in Aleppo, Syria, daughter of a man who apprenticed with a famous astrolabe maker named Bitolus [!!] before she became his student as well. Her designs were so innovative and complex that she was employed by Sayf al-Dawla –the ruler of Aleppo – from 944 to 967. Astrolabes could be used to determine time of day, as well as location, and were often used in Muslim society to determine Qibla, prayer times, and the days to start Ramadan and Eid.”

The claim that astrolabes could be used to determine the days to start Ramadan and Eid is pure fiction.

---

[76] Emily Asher-Perrin, “The Inspiration for Nnedi Okorafor’s *Binti* is a Muslim Scientist From the 10th Century” (2016), at https://www.tor.com/2016/06/02/the-inspiration-for-nnedi-okorafors-binti-is-a-muslim-scientist-from-the-10th-century/ (accessed 2017). For more in Malay see https://fimedia.weebly.com/home/maryam-al-asturlabi (accessed 2017).

On the internet there are now dozens of other citations of the woman astrolabist called Mariam. These two must suffice here. In view of all this dubious information in circulation it is comforting to find a voice of reason, namely, that of Raya Wolfsun, a specialist on astrolabes unlike many historians of science:[77]

> " ... ... Unfortunately, there are many unsupported details widely circulating about her: that her name was Mariam "Al-Asturlabiya" Al-'Ijliya; that she was born in 945 and died in 967 AD; and most notoriously that she invented the astrolabe, or at least made such beautiful astrolabes that she had regular royal commissions.
>
> First of all, I have no idea why so many people think her name was Mariam. (If anyone can shed light on this, please reach out to me!)
>
> The most glaring error is the claim that she invented the astrolabe. There is a mountain of evidence that she did not – for example, the known existence of at least three astrolabe treatises ... written centuries before she was born. Furthermore, all three use the term 'astrolabe', which is noteworthy because I've encountered people who think that 'Al-Asturlabiya' was part of her name and that the astrolabe was named after her. ...
>
> Regarding the claim that her work was especially "beautiful" or "intricate" or "ingenious": we have no idea. We have no surviving instruments attributed to her, nor descriptions thereof. The closest we get is some work attributed to her teacher, Nastulus ... ."

Perhaps one day some Muslim sites will take interest in the other 30-odd astrolabists mentioned by Ibn al-Nadîm, or even in their surviving instruments. Google Arts & Culture has Nastûlus' earliest dated astrolabe, from the Islamic Art Museum in Kuwait, dated too early by some 200 years to a time long before the Muslims came into contact with the astrolabe.[78] *Ma'lêsh*. The actual date of this piece is 927/28, but it is not – *contra* many claims – the oldest surviving astrolabe, for the Archaeological Museum in Baghdad has, or had, one datable to the mid 8th century. On the other hand, the same site has a commendable description of the early-14th-century "Sloane astrolabe" in the British

---

77 Raya Wolfsun, "Concerning "Mariam" Al-Asturlabiya" (2015), at http://www.rayawolfsun.com/2015/02/06/the-romance-of-al-asturlabiya/.

78 Anonymous, "Astrolabe - Nastulus - 101 AH", at https://www.google.com/culturalinstitute/beta/asset/astrolabe/3wH2MHmogO0cGA?hl=en (accessed 2017).

Museum, the most spectacular surviving astrolabe from medieval England.[79]

For the time being, the site mosaicofmuslimwomen.com informs us that:[80]

> "Astrolabes were global positioning instruments [!] that determine the position of the sun and planets [!], so they were used in the fields of astronomy, astrology and horoscopes [!]. They were also used to tell time and for navigation [!] by finding location by latitude and longitude [wow!]. The Muslims used them to find the Qibla [!], prayer times, and determine starting days for Ramadan and Eid [!!]. Basically, an astrolabe is an old fashioned smart phone."

Actually not old-fashioned but at least smart enough to serve as a model of the universe.

Differences between academic colleagues

One problem for the History of Science can be the modern scientists who with no historical training get interested in historical scientific objects or ideas. Even worse than the scientists might be philosophers and art historians. Some of these colleagues have no idea that there is a discipline called History of Science. This is a broad discipline, and at one end are those concerned with "Quellen und Studien", "historical sources and studies thereof". Your local museum has an astrolabe. You study it, every detail of it. You read up on astrolabes. You write up your astrolabe. You publish it. At the other end are those devotees of "Wissenschafts–geschichte", for which there is no translation, but this is a newly-established discipline which has replaced "Geschichte der Natur–wissen–schaften", "History of Science". Your local museum has an astrolabe but you do not go to look at it because you know what an astrolabe looks like; you feel inspired to write a paper philosophizing about the social context of astronomical instrumentation in such and such a milieu in such and such a century. These days it is necessary to add a bit of hype. How about a university course entitled: "The astrolabe as a source for pre-modern astronomy and astrology". Or how about: "For Latin scholars around the year 1000, the astrolabe became the earliest, non-verbal channel to access and assimilate mathematical knowledge from the Arabic culture, and could

---

79 https://www.google.com/culturalinstitute/beta/asset/astrolabe/uQFWdhO5CAQs5A

80 http://mosaicofmuslimwomen.com/2012/01/then-mariam-al-astrolabiya-al-ijliya-scientist-inventor/ (2012), accessed 2017).

be seen as representing a divine 'architectonical rationality' which humans could share in the mathematical experience."?

When a modern astronomer turns his attention to a historical instrument, he is possibly capable of understanding the mechanics of the instrument, as well, perhaps but not necessarily, the use. Consider this extract from an article on instruments before the telescope authored by an astronomer for other astronomers:[81]

> "Some of the problems solved with astrolabes were:
>
> 1. finding the position of the sun on the ecliptic on a given date;
> 2. finding the azimuth of the sun at sunrise on a given date;
> 3. finding the time of sunrise and sunset on a given date;
> 4. finding the sun's altitude at transit on a given date;
> 5. finding the length of daylight on a given date;
> 6. finding the rising azimuth of a star;
> 7. finding the altitude of a star at transit;
> 8. finding the length of time a star would be above the horizon on a given date.
>
> In addition to the predictions [?] above, the astronomer could use the astrolabe to measure the altitude of the sun, moon [!], or stars. Not a bad set of abilities for an instrument that does not use electricity or have even one computer chip!"

All this is more or less correct. I would just change "on a given date" to "on any day of the year", and change "altitude at transit" for the sun or a star to "altitude" at any time of the day or night. And please drop the moon. But I would add the principal practical use of the astrolabe: "finding the time of day or night throughout the year", even without a single chip. And why not illustrate such an important article with some real instruments, instead of cheap imitations?

---

81 Robert A. Egler, "Measuring the Heavens: Astronomical instruments before the telescope", *Journal of the Royal Astronomical Society of Canada* 100 (2006): 37-40, available on adsbit.harvard.edu

An American university History student, Jeremy Schreier, published in 2014 an article "The Portal of the Universe: The astrolabe as a site of exchange in medieval and early modern knowledge".[82] He began:

> "although the astrolabe may seem foreign and inaccessible today, for Chaucer in medieval England, the tool was so crucial to understanding one's place in the universe that he wrote an essay describing how to use the instrument".

He then proceeded to cite a few museum catalogues, but his article gives the impression that he had never actually seen an astrolabe. Or that he thought that Chaucer's treatise was the only one, or the best one, ever compiled? Is the astrolabe really so foreign and inaccessible today? Are we today incapable of comprehending an instrument that was widely known and appreciated in the Middle Ages? And can one really with an astrolabe begin to understand one's place in the Universe?

Various other sites purporting to deal with the astrolabe do not achieve their aspirations of their titles.[83]

An astrolabe made out of stone

An 11th-century stone column some 2 meters high from a monastery outside Regensburg carries on the top a vertical disc, also in stone. On one side of the disc is a meridian circle, orthogonal projections of the celestial equator and the circles of Cancer and Capricorn, as well as the celestial axis, and more. On the other side the image of Aratus kneeling. The ensemble of lines is devised for latitude 48°, which was surely intended to serve the seventh climate as well as Regensburg (latitude *ca*. 49°). The first serious investigator of this piece was the distinguished German historian of astronomy, Ernst Zinner, who in 1923 published it as the "*Regensburger Lehrgerät*", that expression indicating that is was a

---

[82] Jeremy Schreier, "A Portal to the Universe: The Astrolabe as a Site of Exchange in Medieval and Early Modern Knowledge", *Intersect: The Stanford Journal for Science, Technology and Society* 7:2 (2014), available at http://web.stanford.edu/group/ojs3/cgi-bin/ojs/index.php/intersect/article/view/617/505, perhaps also http://www.medievalists.net/2015/01/portal-universe-astrolabe-site-exchange-medieval-early-modern-knowledge/ (2015).

[83] To cite just two examples: Carolyn Collins Petersen, "The Astrolabe: using the stars for navigation and timekeeping" (2017), at www.thoughtco.com/the-astrolabe-using-the-stars-for-navigation-and-timekeeping-4126095 (accessed 2017); and Ertan Karpazli, "Astrolabes: The smart phones of ancient times" (2014), at http://www.worldbulletin.net/filebox/130497/astrolabes-the-smart-phones-of-ancient-times (accessed 2017).

"teaching device".[84] Previously, and again more recently, it had been called an astrolabe and a sundial or a sphere; it is, of course, none of these. It is just a *Lehrgerät*.

Now in 2017 we have a new study of this piece, couched in the jargon of art-historical "comparativism".[85] The author, Ittai Weinryb, persists in referring to it as an astrolabe throughout his paper, without seeming to realize what an absurd name this is for an instrument that has nothing to do with an astrolabe. He inevitably cites neither the classic study of Zinner nor my own comparativistic paper on astronomy in mosques and monasteries, where I also dealt with this charming piece.[86] Weinryb claims that it:

> "presented the semblance of an astrolabe, embodying the relevant technology and knowledge even without functionality. We can put to one side technological debates about possible functionality. For the historian of art focusing on the medieval world, the fact that the object was nonoperational indicates that its significance lay not in its functionality but rather in its place and monumentality [!]. The object *did* function but as a marker, a signifier for the reception of technology, rather than as an object that could inform about the place of the stars or the time of the day."

In fact the piece, which has no semblance of an astrolabe, is perfectly functional, but only for those who have eyes to see. It is nothing more or less than a *Lehrgerät*. It has nothing to do with the stars and nothing to do with time-keeping. Now our author starts talking about real astrolabes, citing the "plethora" of available literature, although it is highly doubtful whether he has consulted any of it since he obviously has no idea what an astrolabe is or does. His next paragraph reads:

> "The astrolabe was a tool with which one gazed into the celestial flow [!] in order to determine the time. A comparison can be made with earlier examples of astrolabes produced in Spain or in the eastern Mediterranean, such as the earliest Latin astrolabe, known as the "Carolingian Astrolabe", a device probably made in Muslim Andalusia

---

[84] Ernst Zinner, "Das mittelalterliche Lehrgerät für Sternkunde zu Regensburg und seine Beziehung zu Wilhelm von Hirsau", *Zeitschrift für Instrumentenkunde* 43 (1923): 278-282.

[85] Ittai Weinryb, "The object in a comparative context", in Jas Elsner, ed., *Comparativism in art history*, Abingdon & New York, 2017, pp. 79-93.

[86] King, "Aspects of practical astronomy in mosques and monasteries", in *Synchrony*, VIII: 847-880, esp. pp. 867-869

> and then engraved in Latin in a monastery in northern Spain. The marking of the latitude at 38°30', which could indicate either Barcelona or Paris, two cities that are in the same latitude, has generated uncertainty about where the piece was made."

The Destombes astrolabe was not made in Islamic al-Andalus. It was made in what is now Catalonia and it resembles no other Islamic astrolabe and no other Latin astrolabe from Spain. We are now confronted with some severe geographical problems. Actually, latitude 38°30' corresponds to Córdoba, with 41°30' for Catalonia and also Rome, and 48°30' perhaps for Paris. But these are not the latitudes found on the plates of the Carolingian astrolabe, except for 41°30', which is explicitly stated to be for ROMA ET FRANCIA, the latter surely referring to "The land of the Franks". And that is where this astrolabe was made, unless it was made in Rome.

Let us return to safer ground and move to the use of the standard astrolabe:

> "An astrolabe such as the Carolingian astrolabe would have been held up high into the sky, making the person holding the astrolabe into the center of the celestial sphere [!]. That person would then adjust the rete according to the position of the tip of the moving alidade, find a star, and calculate his own place in the world [!]. He would then adjust the astrolabe horizontally [!], fixing the rete according to that calculation, and have the celestial sphere projected through the astrolabe [!], with every zodiac [?] and star placed according to the display on the astrolabe. We can be quite certain that this practice was not carried out for the Regensburg astrolabe, not simply because it lacks an alidade [!] but because the stone astrolabe could not be flipped horizontally [!]."

The mind boggles at this art historian's fanciful but nonsensical approach to using an astrolabe. One minor point: the *Regensburger Lehrgerät* could be flipped horizontally but fortunately no art historian has ever tried to do that. Enough of this, but alas there is more – page after page – in the article presenting more about the "Regensburg astrolabe" for comparativist art historians. They may be comforted with the author's assurance:

> "The comparativist approach to such objects may be innovative, but it will surely be informative",

I'm not so sure.

Nabataean astrolabes

Since the 1950s several researchers have proposed that Islam started in N.W. Arabia rather than Mecca. The latest of these, Dan Gibson, believes

that he has proven that Islam started in Petra. Proof of this, he maintains, is that the majority of early mosques face Petra rather than Mecca.[87]

The problem is that these early mosques do no face Petra, and nor do they face Mecca, in the modern sense of being actually and deliberately aligned toward Petra or Mecca. You cannot begin find the direction of a distant location in modern terms unless you do know where it is and where you are. In fact, it is well established, and confirmed by medieval Arabic texts, that early Muslims faced the astronomically-aligned Kaaba in Mecca by means of folk astronomical procedures, that is, using astronomical horizon phenomena.[88] If they do happen to face Petra, it is by coincidence.

Gibson further claimed that these early mosques face Petra so accurately that the earliest Muslims must have had the necessary mathematical and technical skills to achieve this, namely, spherical trigonometry and astrolabes and stuff (by stuff I mean pigeons and things). Of the astrolabe Gibson writes:[89]

> "The astrolabe in Islam. The astrolabe was introduced early on in the Islamic world. Some historians believe that this might have been later in the eighth and ninth centuries when Arab treatises on the astrolabe were published. However by the ninth century these writings indicate a long familiarity with the instrument. The oldest existing instruments are Arabian [*sic*, read Iraqî] from the tenth century [*sic*, read 8th century], and there are nearly 40 instruments from the 11th and 12th centuries. The astrolabe gave Muslims the ability to determine the time of day, and therefore prayer times as well as the Qibla direction. Early astrolabes were based on the Arab compass [!!] that used the rising and setting of different stars. The astrolabe ... has both a front side and rear side, so that calculations can be made [!]. The astrolabe was also known as a Windrose [!]. ... On the astrolabe, latitude was still [*sic*, read never] determined by the height of the pole star using the *iṣba'* and *zām* measurements [of Arab navigational astronomy]. Astrolabes were quite difficult to use at sea because of the rolling of the ships, which made it hard to determine the vertical line accurately. ... ."

---

87 Dan Gibson, *Early Islamic Qiblas*, Vancouver BC: Independent Scholars Press, 2017 (www.academia.edu/33662914/).

88 King, "From Petra back to Mecca – From pibla back to qibla" (2017), available at www.davidaking.academia.edu, also www.muslimheritage.com/article/from-petra-back-to-makka

89 Gibson, *Early Islamic Qiblas*, pp. 159-160.

The problem with this is that the Muslim encounter with the astrolabe took place on the northern border of the new realm, in the city of Harrân, where astrolabes were already being made by folk who knew what they were doing. Another is that early astrolabes were not used to find the qibla. And they have nothing to do with navigation or with the windrose.

When I ventured to mention this in a review of Gibson's book I was viciously attacked by a French Catholic theologian and priest Édouard-Marie Gallez,[90] who came out in support of Gibson and of the 7th- and 8th-century Muslims and their astrolabes in the Hijaz:

> "King prétend que les Arabes ne savaient pas se servir de ce qui tenait lieu alors d'astrolabe. Il est difficile de penser qu'ils étaient incultes à ce point – et ils pouvaient au moins le demander à d'autres." / "King claims that the Arabs [of the 7th and 8th centuries] did not know how to use of what took the place of the astrolabe in those times. It is difficult to imagine that they were so illiterate / unschooled at that time, and they could not at least have asked some other folk."

One has to imagine these Hijazi Arabs running around trying to find the *pibla* to Petra, asking any passing Bedouin or surviving Nabataean or defunct Hagarenes or visiting Judéo-Nazaréen (Gallez' favorites) if they have an appropriate tool.[91]

With this remark of Gallez, singly unschooled in the history of science, we have, so to speak, reached the bottom of the barrel.

Fake astrolabes

The faking of Islamic astrolabes began in Iran in the 19th century and in the past 40 years has moved to India. Far fewer medieval European fakes have been produced. There is a tendency amongst certain colleagues when confronted with an instrument that they do not understand to pronounce: "It must be a fake." This happened to the Destombes astrolabe and the Regiomontanus astrolabe, two of the most historically important astrolabes. In both cases, it was possible, with a great deal of work, to reinstate them. The problem is that the instruments, even after they have

---

90 Édouard-Marie Gallez, "King et Khan : Crone et Cook ont-ils renié leur travail ?" (2017), at www.academia.edu/35454474/

91 King, "Gibson & Gallez – False piblas and fake calumnias or Did the elusive "Judéo-Nazaréens" use astrolabes to negotiate the narrow Siq of Petra?", to appear on davidaking.academia.edu (2018).

been understood and reinstated, never recover from the disgrace, and those who doubted the authenticity of the instruments will never publicly retract their original opinions. "So-and-so said it was a fake" lingers on, "so-and-so didn't like the inscription", ... , one can really feel sorry for the poor instruments abused in this way.

Now "fake" means not genuine and intended to deceive. A 19th-century astrolabe with an inscription purporting to be from the 14th century. A signature of a man whose name is not proper Arabic. Astrolabes in the tradition of a famous astrolabist, astronomically incorrect markings with incorrect Arabic inscriptions and a signature of sorts of the master. Such were the astrolabes which Owen Gingerich showed on photos to George Saliba and myself in Beirut in 1971: we sorted out the real ones, little jewels, from the fake ones, rubbish but still looking alright at first sight.[92]

In the 1990s I spent the morning at Christie's in London just looking at dozens of fake astrolabes in the hope of finding a genuine plate or rete or whatever. Whilst I was there a man came in with an astrolabe which he wanted to have auctioned. I was consulted and I told him it was a piece of trash for tourists; he was not happy. That afternoon I spent at Sotheby's on the same mission. Lo and behold, the same fellow came in with his fake astrolabe. I was consulted again, but now the man was despondent. "I need the money", he said, "what can I do?". He was a pleasant fellow and I wanted to help him. I told him: "Take it to Paris." Long gone are the days when Alain Brieux in the Rue Jacob could also have told him immediately it was a fake, for it was Alain who had landed a modern European instrument faker in prison.[93] Nowadays it is possible for a fake astrolabe to flourish in Paris.

Large-scale fake and fantastic instruments of multiple components made in certain workshops in India in the 1990s for unsuspecting tourists with bulging purses.[94] We should add ill-advised museum curators, because some of this trash was acquired by the Miraj Museum in Abu Dhabi, who

---

92 Gingerich & King & Saliba, "The 'Abd al-A'imma astrolabe forgeries" (1972).

93 Alain Brieux, "Les astrolabes : tests d'authenticité", *Art et curiosité*, sept. 1974, unpaginated.

94 Mentioned in King, *Synchrony*, XIVf: "Brief remarks on astronomical instruments from Muslim India", pp. 797-814, esp. pp. 811-813. A substantial photographic archive was gathered in the 1990s by M. Christopher Roustan Delatour of Boulogne-sur-Mer.

are so proud of it that they even prepared a video of it.[95] One of these objects is or has been being hawked by Barakat Gallery:[96]

> "This piece heralds from India during a period of British occupation and is likely to have been produced in one of the northern Indian workshops that are known to have produced Islamicate style globes as early as 16th-17th centuries and continued well into 20th century."

This is unexpurgated rubbish, and it is an insult both to the serious astrolabists of Lahore and to the British colonialists.

Close to 20 astrolabes, Islamic and European, genuine and fake, are featured in a Greek website by Elpiniki Liberia.[97] Sorting them out might be an interesting exercise for the reader.

The monstrous thing that we shall describe in the next section reminds me of this fake Indian junk.

Astrolabes as a must-have gimmick

Concerning the 2016 season six finale of "The Game of Thrones", *Radio Times* editor Paul Jones writes:[98]

> "As an awestruck Sam makes his way into the vast library at the Citadel, hanging from the ceiling is this device … ... . At first glance it looks as if its function is to reflect sunlight from the window high above around the room via those mirrors ... . But ... ... could the device have a second function? Well, yes, it's called an astrolabe – or more accurately an armillary sphere. And you can actually buy one … ... .
>
> *Game of Thrones Astrolabe and Pop-up Book Set!*
>
> So what does it do? Well, an armillary sphere is a model constructed from revolving hoops representing celestial bodies, their lines of longitude and latitude and so on, usually with the sun or the earth at its centre. It was used to track the movement of the stars and planets and could therefore also show the changing of the seasons. Given that the

---

95 "The Astrolabe. Miraj - The Museum, Abu Dhabi" (2016), at https://www.youtube.com/watch?v=05oSKvQ95JQ (accessed 2017).

96 See http://store.barakatgallery.com/product/islamic-brass-astrolabe-with-five-celestial-globes/ (accessed 2017).

97 Elpiniki Liberia, "Astrolabe: A computer thousands of years", at http://amphipolis.gr/en/αστρολάβος-ένας-υπολογιστής-χιλιάδω/ (accessed 2017).

98 http://www.radiotimes.com/news/2016-06-28/this-reference-to-the-game-of-thrones-title-sequence-in-the-season-6-finale-could-change-everything/ (2017). See also https://www.quora.com/What-is-the-significance-of-the-astrolabe-in-the-Game-of-Thrones-intro,

> Maesters at the Citadel determine when the long seasons of Westeros officially begin and end – sending out white ravens to share the news – it seems likely they are using the armillary globe to help make those decisions."

Here we have a three different instruments combined into one, the first two completely misunderstood, and the third, an armillary globe, an ingenious figment of the author's crass commercial imagination.

Here's another explanation from Angus Wall, Creative Director at *Elastic*, 'the company that created the opening credits map intro':[99]

> "Astrolabes have historically been used by everyone from explorers and navigators to astronomers and even astrologers to locate and predict positions of the planets [does he really mean Mercury, Venus, Mars, *etc*., which are usually called "planets"?] in order to provide local time, latitude, and more. The astrolabe the team at *Elastic* created is much more complex than traditional astrolabes and has intricate rings around it telling the history of Westeros."

There you go.

Concluding remarks

Fake news on astrolabes will continue to flourish because a little astronomy, a little history, a little imagination, is perhaps too much to ask for, yet it is necessary before one can begin to understand what an astrolabe is. This is, alas, not the only topic which suffers in this way. For example, the whole field of the history of Islamic science – let us not forget that Muslim scientists were the leaders in their field from the 9th to the 16th century – much of what is now found on the internet written by amateurs or eager students is an insult to the memory of those scientists. And now we have reached the age when professors of this and that can publish a scholarly-looking, apparently well-documented overview of the history of Islamic science without even being aware of any fundamental contributions of the Muslim scholars and being clueless about the basic

---

99 http://www.businessinsider.com/game-of-thrones-astrolabe-title-sequence-2016-6?IR=T (site somewhat fluid)

research that has been done on the subject over the past 200 years.[100] But in this new age, anything goes. And now we have a new buzz phrase "astrolabes in context". Where astrolabes belong is of course in the history of astronomy in Islamic or medieval European society. But the world is not interested in what astronomers did in times of yore with observations, tables and calculations. Calculations and tables are not sexy, but astrolabes most certainly are. And it is hard to convince people that astrolabes constitute but a small part of astronomy in those societies. Or to convince them that a mariner's astrolabe is not an astrolabe but an inclinometer.

I have certainly not exhausted the fake news about astrolabes. The reader can look for more on a site of the Mariners' Museum in Newport News, Virginia.[101] Or how about the fake news of an Islamic astrolabe having been discovered in Spain,[102] the Islamic astrolabe in question being a Hebrew one and not having been discovered at all!

This author was fairly confused by a so-called Haiku Deck presentation promising to display an ordered series of images of a Hebrew astrolabe.[103] In fact, images of bits and pieces of three Hebrew astrolabes, each of which I had published, were presented, along with some astronomical and mathematical snippets that, like the astrolabe snippets, could not, with an appropriate commentary, conceivably serve any educational purpose. Yet the Deck apparently serves over a million *innocenti* worldwide. One of their images shows a Fusoris astrolabe, from early-15th-century France, labelled ASTROLOBE, which endears them to me so much that I have included it at the beginning of Part II.[104]

---

[100] To cite just three examples: Giovanna Lelli, "Arab-Islamic Reception and Development of Hellenistic Science", *Advances in Historical Studies* 4 (2015): 29-42; M. Fernini, "Astronomy at the service of the Islamic society", in D. Valls-Gabaud & A. Boksenberg, eds., *The Role of astronomy in society and culture*, in *Proceedings of International Astronomical Union (IAU) Symposium No. 260*, 2009, pp. 514-521; and Khalid Chaouch, "L'Astronomie arabe vue par les Occidentaux," *La revue des deux rives : Europe-Maghreb* (2001), pp. 119-138.

[101] Anonymous, article "Astrolabe" at http://exploration.marinersmuseum.org/object/astrolabe/ (accessed 2017).

[102] http://history2701.wikia.com/wiki/Islamic_Astrolabe_Discovered_in_Spain (accessed 2017).

[103] https://www.haikudeck.com/copy-of-hebrew-astrolabe-uncategorized-presentation-c1ad5a6013#slide17 (accessed 2017).

[104] https://www.haikudeck.com/astrolobe-uncategorized-presentation-eadf4a7632 (accessed 2017).

Alternatively, any interested person can find quite a bit more on the discoverislamicart.org site.[105] Here there are a few Islamic astrolabes presented from various museums. For most pieces, only the fronts can be seen, which is not a good start. But for each piece we get a statement, usually absurd but at least novel, about what an astrolabe is, and some strange information about each piece, with many Arabic names incorrectly spelled. One of the pieces illustrated is a worthless fake, and it bears no relation to the genuine instrument whose description accompanies it. The descriptions are written by museum curators, who, with few exceptions, have no idea about the state of the field regarding astronomical instruments or the regional history of Islamic astronomy.

CNN these days has a cute reminder, call it a warning, about fake news in this age of twits and tweets: An apple is an apple, whether you look at it from the left or the right. Some people might say that it is a banana, but that does not change the fact that it is an apple.[106]

---

105 http://www.discoverislamicart.org/ (accessed 2017).

106 https://www.youtube.com/watch?v=vckz6EAn30Y (accessed 2017).

Bibliography

Note: The following works relate to Part I. The sources used for Part II are not listed here. The entries are not ordered alphabetically so that the reader can spend more time surveying them. The general works on the history of astronomy provide the context for instruments in general and astrolabes in particular. Works containing a substantial number of relevant articles are dissected. The selection of works is based on a preference for early instruments. The two dozen most significant works for astrolabes to *ca*. 1500 are printed bold. A more detailed bibliography for secondary literature up to *ca*. 2005 is given in King, *Synchrony*, vol. 2.

General works on the history of astronomy

James Evans, *The History and practice of ancient astronomy*, New York & Oxford, 1998.

Christopher B. F. Walker, ed., *Astronomy before the telescope*, London, 1996 (contains chapters on Byzantine, Islamic, Hebrew, Indian, medieval European and Renaissance astronomy, as well as late medieval and Renaissance instruments)

Steven C. McCluskey, *Astronomies and cultures in Early Medieval Europe*, Cambridge *etc*., 1998

King & Julio Samsó & Bernard R. Goldstein, "Astronomical handbooks and tables from the Islamic world (750-1900): An interim report", *Suhayl – International Journal for the History of the Exact and Natural Sciences in Islamic Civilisation* (Barcelona) 2 (2001): 9-105

José Chabás, "Aspects of Arabic influence on astronomical tables in Medieval Europe", *Suhayl* 13 (2014): 23-40

David C. Lindberg & Michael H. Shank, eds., *The Cambridge History of Science*, vol. 2: *Medieval Science*, Cambridge, *etc*., 2014 (chapters on Islamic, Byzantine, and medieval European astronomy)

Glen M. Cooper, "Astrolabes and *zīj*es as tools of education and the transmission of scientific knowledge from Islamic civilization" (2017) available at: www.academia.edu/32027584/ (accessed 2017)

Barbara Freyer Stowasser, *The day begins at sunset - Perceptions of time in the Islamic world*, New York: I. B. Tauris, 2014 (includes a sound non-technical introduction to the astrolabe)

General introductions to the astrolabe

John D. North, “The Astrolabe”, *Scientific American* 230 (1974), pp. 96-106 (timeless, the place to start)

Greenwich Astrolabe Booklet: *The Planispheric Astrolabe*, Greenwich: National Maritime Museum, 1976 (still available?)

Willy Hartner, “The Principle and Use of the Astrolabe”, in Arthur Upham Pope, ed., *A Survey of Persian Art*, 9 vols., London & New York, 1938-39, III, pp. 2530-2554, repr. in *idem*, *Oriens-Occidens*, Hildesheim, 1968, pp. 287-311 and pp. 312-318

Paolo Trento, *L’astrolabio – storia, funzioni, costruzione*, Rome, 1989

Margarida Archinard, *Astrolabe*, Geneva, 1983

Henri Michel, *Traité de l’astrolabe* , Paris, 1947, repr. 1989 (still valuable)

Emmanuel Poulle, “L’astrolabe”, *La Recherche* (Paris) 178 (juin, 1986): 756-765

Josep Chabàs & Daniel Bosch, *L’astrolabi pla – Guia per a la construcció i utilització*, Barcelona, 1987 (excellent)

James Evans, *The History and practice of ancient astronomy*, New York & Oxford, 1998, pp. 141-161

James E. Morrison, *The astrolabe*, at http://www.astrolabes.org/index.htm (the best available website)

Petra G. Schmidl, “‘Mirror of the stars’: The astrolabe and what it tells about pre-modern astronomy in Islamic societies”, in Sonja Brentjes & Taner Edis & Lutz Richter-Bernburg, eds., 1001 distortions – How (not) to narrate history of science, medicine, and technology in non-Western cultures, Würzburg: Ergon, 2016, pp. 173-187

Glen M. Cooper, “Astrolabes and *zījes* as tools of education and the transmission of scientific knowledge from Islamic civilization” (2017) available at: https://www.academia.edu/32027584/ (accessed 2017).

Silke Ackermann, podcast: “Al-Mizan: Astrolabes in cultural context” (2011), at https://podcasts.ox.ac.uk/al-mizan-astrolabes-cultural-context (accessed 2017)

Hüseyin Sen, astrolabe workshops listed in uu.academia.edu/HuseyinSen

Selected satisfactory websites and videos

Note: All sites accedded 2017

Oxford MHS: www.mhs.ox.ac.uk/astrolabe/

Florence MG: www.museogalileocatalogue.pdf

EPACT: https://www.mhs.ox.ac.uk/epact/introduction.php

Frankfurt medieval instrument catalogue: http://www.davidaking.org/instrument-catalogue.htm (astrolabe descriptions available upon request – so far one request in 25 years!)

James Morrison's astrolabe site: https://www.astrolabes.org/

S. R. Sarma's catalogue of Indian astrolabes: http://www.srsarma.in/catalogue.php

Site of Martin Brunold, maker of copies of historical instruments: www.astrolabe.ch

Emily Winterburn, "Using an astrolabe" (2005), at http://www.muslimheritage.com/article/using-astrolabe

Tom Wujec, "Learn to use the 13th-century astrolabe" (2009), at https://www.ted.com/talks/tom_wujec_demos_the_13th_century_astrolabe

Marc Goutaudier & Denis Savoie, "L'Astrolabe", at https://www.youtube.com/watch?v=c6Ab5oMIMoc

Anonymous, "L'Astrolabe", at http://www.meridienne.org/index.php?page=astrolabe.presentation

Anonymous, "Astrolabium" at http://www.diewahrheitimherzen.net/islam-wissenschaft/298-astrolabium

Aaron Powner, "Using an astrolabe" (2012) at https://www.youtube.com/watch?v=7COCkxpEvzs

"Using an Astrolabe to tell the time", at www.mhs.ox.ac.uk/exhibits/using-an-astrolabe-1/

An elegant and informative video of the parts of an astrolabe moving in accordance with the rotating heavens produced by L'Institut du Monde Arabe in Paris is entitled "L'astrolabe" (2014), at www.youtube.com/watch?v=c6Ab5oMIMoc

Richard Wymarc, "The astrolabe project – An obsession in progress" (2017), at http://www.astrolabeproject.com

See also the praiseworthy programme "Physik der Renaissance" of the Gymnasium (academic high-school) in Lauf near Nuremberg, at http://www.physik.de.rs

Islamic and European astrolabes and astronomical instruments

King, "Astronomical instrumentation in the Islamic world" (first published in *Gli strumenti*, Turin, 1991), new version in *Synchrony*, X: 1-110

– , "The Neglected Astrolabe – A supplement to the standard literature on the favourite astronomical instrument of the Middle Ages" (first version 1996), in *Synchrony*, XIIIa: 339-402

– , "Astronomical instruments between East and West", in *Kommunikation zwischen Orient und Okzident*, Harry Kühnel, ed., Vienna, 1994, pp. 143-198, repr. in *idem*, *Astrolabes from Medieval Europe*, I (the first overview of Byzantine, Islamic and medieval European instruments in general)

Emmanuel Poulle, *Un constructeur d'instruments astronomiques au 15e siècle – Jean Fusoris*, Paris, 1963

– , "Les instruments astronomiques du Moyen Âge", 1st edn. in *Le Ruban rouge*, no. 32 (mars 1967), pp. 18-29, repr. by the Museum of the History of Science, Oxford: Selected off-prints, no. 7; 2nd edn. with different plates in *Astrolabica* 3, Paris: Société internationale de l'Astrolabe, 1983

London 2014 Conference Proceedings**:** Josefina Rodríguez Arribas & Charles Burnett & Silke Ackermann, eds., ***Astrolabes in medieval cultures*****,** a special issue of *Medieval encounters* 23 (2017). Contents:

Johannes Thomann, "Astrolabes as eclipse computers: Four early Arabic texts on construction and use of the *safîha kusûfiyya*"

Josefina Rodrîguez-Arribas, "The astrolabe finger ring of Bonetus de Latis: Study, Latin text, and English translation with commentary"

Emilia Calvo, "Some features of the Old Castilian Alfonsine translation of 'Alī Ibn Khalaf's treatise on the *Lámina universal*"

Flora Vafea, "From the celestial globe to the astrolabe: Transferring celestial motion onto the plane of the astrolabe"

Petra G. Schmidl, "Knowledge in motion: An early European astrolabe and its possible medieval itinerary"

Sreeramula Rajeswara Sarma, "A m onumental astrolabe made for Shâh Jahân and later reworked with Sanskrit legends"

Miquel Forcada, "*Saphaeae* and *hay'āt*: The debate between instrumentalism and realism in al-Andalus"

Laura Fernández Fernández, "Astrolabes on parchment: The astrolabes depicted in Alfonso X's *Libro del saber de astrología* and their relationship to contemporary instruments"

John Davis, "Fit for a King: Decoding the Great Sloane Astrolabe and other English astrolabes with 'quatrefoil' retes"

King, "European astrolabes to *ca*. 1500: An ordered list"

Taro Mimura, "Too many Arabic treatises on the operation of the astrolabe in the medieval Islamic world: Athīr al−Dīn al-Abharī's treatise on knowing the astrolabe and his editorial method

Günther Oestmann, "Changing the angle of vision: Astrolabe dials on astronomical clocks"

Azucena Hernández, "Astrolabes for the King: The Astrolabe of Petrus Raimundi of Barcelona"

Giorgio Strano, "A new approach to the star data of early planispheric astrolabes"

Islamic astronomical instruments

AIOS*: Fuat Sezgin *et al.*, eds., *Astronomische Instrumente in orientalistischen Studien, 6 vols., Frankfurt, 1990-91, repr. as I*slamic Mathematics and Astronomy*, vols. 85-90 (1998), with 6 further vols. *ibid*., vols. 91-96 (1998) (reprints of studies of Islamic instruments from the 19th and early 20th century: **a monumental total of over 5,000 pages**)

Alan Brieux & Francis R. Maddison, *Répertoire des facteurs d'astrolabes et de leurs œuvres*, Paris: C.N.R.S. with Brepols, Turnhout, to appear in 2018

Leon A. Mayer, *Islamic astrolabists and their works*, Geneva, 1956 (a fundamental study, now out of date but unsurpassed because the *Répertoire* has not appeared yet)

The Encyclopaedia of Islam, new edn., 11 vols. and supplements, Leiden: E. J. Brill, 1960-80, especially articles "Asturlâb" (astrolabe), "Matâli'" (right and oblique ascensions), "Mizwala" (sundial), "Rub'" (quadrant), "Shakkâziyya" (universal projections), "Tâsa" (magnetic compass) (also available in French), and *Encyclopaedia of Islam Three*, Leiden, 2007, article "Astrolabes, quadrants and computing devices"

King, *Islamic astronomical instruments*, London: Variorum, 1987/1995. Contains:

II	The medieval Yemeni astrolabe in the Metropolitan Museum of Art in New York
III	The origin of the astrolabe according to the medieval Islamic sources
IV	A note on the astrolabist Nastûlus/Bastûlus

– , ***In Synchrony with the Heavens – Studies in astronomical timekeeping and instrumentation in Islamic civilization***, 2 vols., 1: *The Call of the Muezzin*, & 2: *Instruments of Mass Calculation*, Leiden & Boston, 2005 (vol. 1 deals with astronomical timekeeping, vol. 2 with instrumentation). Contains:

I A survey of tables for timekeeping by the sun and stars
II A survey of tables for regulating the times of prayer
III A survey of arithmetical shadow-schemes for time-reckoning
VIII Aspects of practical astronomy in mosques and monasteries
X Astronomical instrumentation in the medieval Islamic world
XI An approximate formula for timekeeping (750-1900)
XIIa On the universal horary quadrant for timekeeping by the sun
XIIb On universal horary dials for timekeeping by the sun and stars
XIII Selected early Islamic astrolabes, preceded by a general overview of astrolabes
XIIIa The neglected astrolabe – A supplement to the standard literature on the favourite astronomical instrument of the Middle Ages
XIIIb The oldest astrolabe in the world, from 8th-century Baghdad
XIIIc The earliest astrolabes from Iraq and Iran (ca. 850 - ca. 1100)
XIIId A medieval Italian testimonial to an early Islamic tradition of non-standard astrolabes
XIIIe On the origin of the astrolabe according to medieval Islamic sources
XIV Selected late Islamic astrolabes
XIVa An astrolabe made by the Yemeni Sultan al-Ashraf
XIVb Some astronomical instruments from medieval Syria
XIVc A monumental astrolabe for the Ayyubid Sultan al-Mu'azzam
XIVd An astrolabe for the Sultan Ulugh Beg
XIVe Two astrolabes for the Ottoman Sultan Bayezit II
XIVf Brief remarks on astronomical instruments from Muslim India
XIVg A universal astrolabe from 17th-century Lahore
XV An astrolabe from medieval Spain with inscriptions in Hebrew, Arabic and Latin
XVI The geographical data on early Islamic astronomical instruments
XVII The quatrefoil as decoration on astrolabe retes
XVIII A checklist of Islamic astronomical instruments to *ca*. 1500, ordered chronologically by region

Fuat Sezgin, "Astronomical instruments", *chapter in Science and Technology in Islam: Introduction to the history of Arabic-Islamic sciences*, Frankfurt: IGAIW, 2003, at www.ibttm.org/ENG/museum/collection/2-3.pdf

Medieval European astrolabes

Sara Schechner Genuth, "Astrolabes: A cross-cultural and social perspective", in Webster & Webster, *Western Astrolabes* (in Chicago AP), pp. 2-25

– , "Astrolabes and medieval travel", ch. 13 of Robert Bork & Andrea Kann, eds., *The art, science, and technology of medieval travel*, Aldershot & Burlington VT: Ashgate, 2008, pp. 181-210

Saragossa 1994 Conference Proceedings*: **Wesley M. Stevens, Guy Beaujouan and Anthony J. Turner, eds., ***The Oldest Latin Astrolabe, (*Physis* 32:2-3), Florence, 1995. Contains:

Preface - Introduction (Wesley Stevens)

Destombian discovery and doubt, the problem of the 'oldest Latin astrolabe' (Anthony Turner)

La provenance de l'astrolabe 'Carolingien' de Marcel Destombes (Jan de Graeve)

Latin planetary studiesin the IXth and Xth centuries (Bruce Eastwood)

La littérature astrolabique latine jusqu'au XIIIe siècle (Emmanuel Poulle)

Roma et Francia (= Ifranja) in M. Destombes' Carolingian astrolabe (Julio Samsó)

Paleographical studies of letter forms on the mater and tympana of astrolabe AI. 86-31 (Wesley Stevens)

Analyse paléographique de l'astrolabe 'carolingien' (Anscari Mundó)

Traités byzantins sur l'astrolabe (Anne Tihon)

The earliest known European astrolabe in the light of other early astrolabes (David King)

Étude comparative entre l'astrolabe dit 'carolingien' et l'astrolabe d'Abu-Bakr ibn Yusuf de Tou1ouse" (Raymond d'Hollander)

The craftsmanship of the 'Carolingian' astrolabe, IC 3042 (Gerard Turner)

Nouvelles analyses de l'astrolabe latinAI.8631 (B. Gratuze & J. N. Barrandon)

L'authenticité de l'astrolabe dit 'carolingien' (Guy Beaujouan)

King, ***Astrolabes from Medieval Europe***, Aldershot & Burlington VT: Variorum, 2011 (deals with various astrolabes as well as the universal horary quadrant and dials):

I Astronomical instruments between East and West
II The earliest European astrolabe in the light of other early astrolabes
III Rewriting history through instruments: The secrets of a medieval astrolabe from Picardy
IV The medieval Catalan astrolabe of the Society of Antiquaries, London
V A remarkable Italian astrolabe from *ca*. 1300 – Witness to an ingenious Islamic tradition of non-standard astrolabes
VI An astrolabe from Einbeck datable *ca*. 1330
VII The star-names on three 14th-century astrolabes from Spain, France and Italy
VIII A *vetustissimus* Arabic text on the *quadrans vetus*
IX 14th-century England or 9th-century Baghdad? New insights on the origins of the elusive astronomical instrument called the *Navicula de Venetiis*
X The astrolabe depicted in the intarsia of the *Studiolo* of Archduke Federico in Urbino
XI The astrolabe presented by Regiomontanus to Cardinal Bessarion in 1462
XII An ordered list of European astrolabes up to *ca*. 1500

London 2014 Conference Proceedings: see above

Ordered lists of astrolabes

Derek J. de Solla Price, with Sharon L. Gibbs and Janice Henderson, *A Computerized Checklist of Astrolabes*, New Haven CT: Yale University, Department of History of Science and Medicine, 1973 (privately distributed; still invaluable)

King, "A Checklist of Islamic astronomical instruments to *ca.* 1500, ordered chronologically by region", *in Synchrony, XVIII: 993-1020,* and "An ordered list of European astrolabes up to *ca.* 1500", in *Astrolabes from Medieval Europe*, XII, and *London 2014 Conference Proceedings*, pp. 355-364 (both lists are on the author's webpage)

Major studies of astrolabes

Robert T. Gunther, *The Astrolabes of the World*, 2 vols., Oxford, 1932, repr. in 1 vol., London, 1976

Burkhard Stautz, *Untersuchungen von mathematisch-astronomischen Darstellungen auf mittelalterlichen Instrumenten islamischer und europäischer Herkunft*, Bassum, 1997 (studies of the star-positions on the astrolabe retes)

King, "Bringing astronomical instruments back to earth: The geographical data on medieval astrolabes (to *ca.* 1100)", in Arjo Vanderjagt & Lodi Nauta, eds., *Between Demonstration and Imagination: Essays in the History of Science and Philosophy presented to John D. North*, Leiden, 1999, pp. 3-53, repr. in *Synchrony*, XVII

Textual studies (selected)

Otto Neugebauer, "The early history of the astrolabe", *Isis* 40 (1949): 240-256

Anne Tihon, "Traités byzantins sur l'astrolabe", in *Saragossa 1994 Conference Proceedings*, pp. 323-357.

François Charette & Petra Schmidl, "Scientific initiative in 9th-century Baghdad: al-Khwârizmî on the astrolabe and other portable instruments", *SCIAMVS* 5 (2004): 101-198

Richard P. Lorch, *Al-Farghânî – On the Astrolabe – Arabic text with translation and commentary*, Stuttgart, 2005.

Mercè Viladrich, *"El "Kitâb al-Amal bi-l-asturlâb" (Llibre de l'ús de l'astrolabi) d'Ibn al-Samh*, Barcelona: Institut d'Estudis Catalans, 1986

J. Lennart Berggren, "Abû Sahl al-Kûhî's Treatise of the astrolabe with proof: Text, translation and commentary", *Physis: Rivista internazionale di Storia della scienza,* N.S., 31 (1994): 141–252

Ramon Martí and Mercè Viladrich, "En torno a los tratados de uso del astrolabio hasta el siglo XIII en al-Andalus, la Marca Hispánica y Castilla", in Vernet, *ed.*, *Nuevos estudios*, pp. 9-74

Laura Fernández Fernández, “Astrolabes on parchment: The astrolabes depicted in Alfonso X’s *Libro del saber de astrologia* and their relationship to contemporary instruments”, *London 2014 Conference Proceedings = Medieval encounters* 23 (2017): 287-310

Arianna Borrelli, *Aspects of the Astrolabe – “architectonica ratio” in tenth- and eleventh-century Europe*, Stuttgart, 2008

Louis-Amélie Sédillot, “Mémoire sur les instruments astronomiques des Arabes”, *Mémoires de l’Académie Royale des Inscriptions et Belles-Lettres de l’Institut de France* 1 (1844), pp. 1-229, repr. Frankfurt am Main: IGAIW, 1989

Jean-Jacques Sédillot, *Traité des instruments astronomiques des Arabes composé au treizième siècle par Aboul Hhassan Ali de Maroc ...* , 2 vols., Paris: Imprimerie Royale, 1834-1835, repr. in 1 vol., Frankfurt am Main: IGAIW, 1985

Taro Mimura, “Too many Arabic treatises on the operation of the astrolabe in the Medieval Islamic world: Athīr al-Dīn al-Abharī’s treatise on knowing the astrolabe and his editorial method”, *London 2014 Conference Proceedings = Medieval encounters* 23 (2017): 365-403

Robert Fisher & Edgar Laird, *Pèlerin de Prusse on the Astrolabe (1362)*, Binghamton NY, 1995

François Charette, *Mathematical instrumentation in fourteenth-century Egypt and Syria -- The illustrated treatise of Najm al-Dîn al-Misrî*, Leiden, 2003 (analysis of over 100 instrument-types, mainly astrolabes, quadrants and sundials)

Universal plates and the universal astrolabe

Emilia Calvo, *Abû ‘Alî al-Husayn ibn Bâso: Tratado sobre la lámina general para todas las latitudas*, Madrid, 1993

– , “Ibn Bâso’s Astrolabe [plate] in the Maghrib and East”, in *Vernet Festschrift*, II, pp. 755-767

– , “A Study of the use of Ibn Bâso’s universal astrolabe plate”, *Archives internationales d’histoire des sciences* 50 (2000):264-295

Roser Puig, *Los tratados de construcción y uso de la azafea de Azarquiel*, Madrid, 1987

– , “Instrumentos universales en al-Andalus”, in *Madrid MAN 1992 Exhibition Catalogue*, pp. 67-73

– , “Proyección ortográfica en los instrumentos astronómicos del Oriente islámico a la Europa del Renacimiento”, *Revista del Instituto Egipcio de Estudios Islámicos en Madrid* 26 (1993-94): 249-261

– , “Concerning the *safîha shakkâzîya*”, *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 2 (1985): 123-139.

– , *al-Shakkîziyya – Ibn al-Naqqâsh al-Zarqâlluh, edición, traducción y estudio*, Barcelona, 1986

– , "Al-Zarqâlluh's graphical method for finding lunar distances", *Centaurus* 32 (1989): 294-309 (explains the simple but brilliant "Circle of the Moon" on his universal plate)

Emmanuel Poulle, "Un instrument astronomique dans l'occident latin – la 'saphea'", *Studi Medievali* 10 (1969): 491-510

The spherical astrolabe and linear astrolabe

Henri Michel, "L'Astrolabe linéaire", *Ciel et terre* 59 (1943), 101-107

Roser Puig, "Ibn al-Arqam al-Numayrî (m. 1259) y la introducción en el-Andalus del astrolabio lineal, in Juan Vernet, ed., *Nuevos estudios sobre astronomía española en el siglo de Alfonso X*, Barcelona, 1983, pp. 101-103

Francis R. Maddison, "15th-century spherical astrolabe", *Physis* 4 (1962): 101-109

Ernesto Cannobio, "An important fragment of a West Islamic spherical astrolabe", *Annali dell'Istituto e Museo di Storia della scienzia di Firenze* 1 (1976): 37-41

The mariner's astrolabe

Alan Stimson, *The Mariner's Astrolabe – A survey of known surviving sea astrolabes*, Utrecht, 1988

F. Castro, N. Budsberg, J. Jobling & A. Passen, "The Astrolabe Project", *Journal of Marine Archaeology* (2015)

Catalogues of astrolabes in major collections

Bernkastel-Kues: J. Hartmann, "Die astronomischen Instrumente des Kardinals Nikolaus Cusanus", Göttingen, 1919, 56 pp., 12 pls.

Chicago AP = Adler Planetarium: Roderick and Marjorie Webster, *Western Astrolabes* ... , and David Pingree, *Eastern Astrolabes* ... , Chicago, 1998 & 2009, includes:

- Sara Schechner Genuth, "Astrolabes: A cross-cultural and social perspective", in *Western Astrolabes*, pp. 2-25

Delhi: George R. Kaye, "Astronomical Instruments in the Delhi Museum", *Memoirs of the Archaeological Survey of India*, no. 12, Calcutta, 1921

Greenwich NMM: Koenraad van Cleempoel, ed., *Astrolabes in Greenwich. A Catalogue of the Planispheric Astrolabes in the National Maritime Museum*, Oxford, 2006. Contains the following important essays:

- The provenance of the astrolabe collection at the National Maritime Museum (van Cleempoel)
- The construction and use of the astrolabe (David Proctor)
- The literature of the astrolabe to 1450 (Richard Lorch)
- From brass to text: the European astrolabe in literature and print (Anthony Turner)
- The stars on the astrolabe (Paul Kunitzsch)
- Exploring the retes of astrolabes (Elly Dekker)
- Astrological scales on the Greenwich astrolabes (Silke Ackermann)
- The problem of authenticity (van Cleempoel)

- Representations of astrolabes in Western art (van Cleempoel)
- Fake astrolabes

Hyderabad: Sreeramula Rajeswara Sarma, *Astronomical Instruments in the Salar Jung Museum*, Hyderabad: Salar Jung Museum, 1996

Istanbul: yok

Kuwait: King, "Early Islamic astronomical instruments in Kuwaiti collections", in Arlene Fullerton & Géza Fehérvári, eds., *Kuwait: Art and architecture – A collection of essays*, Kuwait, 1995, pp. 76-96

Leiden MB: Robert H. van Gent, *The Portable Universe – Two astrolabes of the Museum Boerhaave*, Leiden: Museum Boerhaave, 1994

Linton Collection Catalogue: *Scientific Instruments and Rare Books from the Collection of Leonard Linton, Point Lookout, N.Y.*, Paris: Alain Brieux, 1980 (a private collection eventually scattered)

London BM: F. A. B. Ward, *A Catalogue of European Scientific Instruments in ... the British Museum*, London, 1981 (problematic, see Price, "Instruments in the BM", *Journal for the History of Astronomy* 13 (1982): 129-132)

London Khalili Collection: Francis Maddison and Emilie Savage-Smith, *The Nasser D. Khalili Collection of Islamic Art*, vol. XII: *Science, Tools and Magic*, 2 pts., London, 1997

Munich: Burkhard Stautz, *Die Astrolabiensammlungen des Deutschen Museums und des Bayerischen Nationalmuseums*, Munich, 1999

Nuremberg: David A. King, "Die Astrolabiensammlung des Germanischen Nationalmuseums", in *Focus Behaim-Globus*, 2 vols., Nuremberg, 1992, I, pp. 101-114, and II, pp. 568-602, 640-643

Oxford MHS: see Gunther above and EPACT

Paris IMA: Jeanne Mouliérac, "La Collection Marcel Destombes", in *Astrolabica No. 5 – Études 1987-1989*, Paris: Institut du Monde Arabe & Société Internationale de l'Astrolabe, 1989, pp. 77-126

Rampur: Sreeramula Rajeswara Sarma, *Astronomical Instruments in the Rampur Raza Library*, Rampur: Rampur Raza Library, 2003

Rockford TM (former): Anthony J. Turner, *Astrolabes, astrolabe related instruments*, Rockford, Ill.: The Time Museum, 1985 (collection now in Chicago AP?)

Spain: Salvador García Franco, *Catálogo crítico de los astrolabios existentes en España*, Madrid, 1945 (now replaced by Hernández Pérez, *Astrolabios en España*)

Strasbourg: Francis Debeauvais & Paul-André Befort, *Cueillir les étoiles – Autour des astrolabes de Strasbourg*, Strasbourg, 2002

Toulouse MPD: Raymond d'Hollander, *L'astrolabe – les astrolabes du Musée Paul Dupuy*, Toulouse, 1993

Washington NMAH: Sharon Gibbs with George Saliba, *Planispheric astrolabes from the National Museum of American History*, Washington DC, 1984

King, "Cataloguing medieval Islamic astronomical instruments", *Bibliotheca Orientalis* 57 (2000), cols. 247-258

– , “Medieval Astronomical Instruments: A catalogue in preparation”, *Bulletin of the Scientific Instrument Society* 31 (Dec., 1991): 3-7

Regional studies

Germany: Ernst Zinner, *Deutsche und niederländische astronomische Instrumente des 11.-18. Jahrhunderts*, 2nd edn., Munich, 1967, repr. 1972

India: Sreeramula R. Sarma, *A descriptive catalogue of Indian astronomical instruments*, at http://www.srsarma.in/catalogue.php

Iraq: King, *Synchrony*, XIII: 403-544: **“The earliest astrolabes from Iraq and Iran”**

Spain: Azucena Hernández Pérez, *Astrolabios en la España medieval: de al-Andalus a los reinos cristianos*, doctoral thesis, Madrid (Computense), 2016 (detailed scientific and art-historical descriptions of some 50 astrolabes)

Syria: King, “L’astronomie en Syrie à l’époque islamique”, in *Paris IMA 1993 Exhibition Catalogue*, pp. 386-395, and [“Instruments astronomiques syriens”], pp. 432-443 & 480, and pp. 485-487; original English text expanded in *Synchrony*, XIVb: 659-724 **“Astronomical instruments from medieval Syria”**

Studies of Indian astrolabes

For Prof. Sarma’s catalogue of Indian astrolabes see above.

Sreeramula Rajeswara Sarma, “Yantrarâja: the astrolabe in Sanskrit”, *Indian Journal of History of Science* 34 (1999): 145-158

-- , “Astronomical instruments in Mughal miniatures”, *Studien zur Indologie und Iranistik* 16-17 (1992): 235-276

– , Indian astronomical and time-measuring instruments: A catalogue in preparation”, *Indian Journal of History of Science* 29:4 (1994): 507-528

– , “The Lahore family of astrolabists and their ouvrage”, *Studies in History of Medicine and Science* (Hamdard University, Hamdard Nagar, New Delhi) 13 (1994): 205-224

– , “The safîha Zarqâliyya in India”, in *Vernet Festschrift*, II, pp. 719-735

– , “Sultan, Sûri and the astrolabe”, *Indian Journal of History of Science* 35 (2000): 129-147

—, *The Archaic and the Exotic: Studies in the History of Indian Astronomical Instruments,* Manohar, New Delhi 2008

— , “Lālah Bulhomal Lāhorī and the production of traditional astronomical instruments at Lahore in the nineteenth century”, *Indian Journal of History of Science,* 50.2 (2015): 259-305

—, “Yantrarāja for Dāmodara: the earliest extant Sanskrit Astrolabe” in J. M. Delire, ed., *Astronomy and Mathematics in Ancient India – Astronomie et Mathématiques de l’Inde ancienne,* Leuven: Peeters, 2012, pp. 87-120

— "The Gurmukhi Astrolabe of the Maharaja of Patiala", *Indian Journal of History of Science,* 47.1 (2012): 63-92.

—, "Yantrarāja at Edinburgh: On a Sanskrit Astrolabe made for Maṇirāma in AD 1644' in S. R. Sarma & Gyula Wojtilla, eds., *Scientific Literature in Sanskrit,* (Proceedings of the 13th World Sanskrit Conference, Section 8), Motilal Banarsidass, Delhi , 2011, pp. 77-110.

—, "A Bilingual Astrolabe from the Court of Jahāngīr," *Indian Historical Review,* 38.1 (June 2011): 77-117

Exhibition catalogues

Madrid MAN 1992 Exhibition Catalogue: *El legado científico andalusí*, Juan Vernet and Julio Samsó, eds., Madrid: Ministerio de Cultura, 1992. [A catalogue of an exhibition at the Museo Arqueológico Nacional, Madrid, during April-June, 1992.]

Paris IMA 1993 Exhibition Catalogue: Sophie Cluzan *et al*., eds., *Syrie, mémoire et civilisation*, Paris, 1993. [Catalogue of an exhibition at the Institut du monde arabe during 1993-94.]

Santa Cruz 1985 Exhibition Catalogue: Juan Vernet, Julio Samsó *et al*., *Instrumentos astronomicos en la España medieval: Su influencia en Europa* (in Spanish and English), Santa Cruz de la Palma, 1985. [Catalogue of an exhibition held in Santa Cruz during June and July, 1985.]

Renaissance astrolabes

Koenraad van Cleempoel, *Instrumentos cientificos del siglo XVI – La corte española y la escuela de Lovaina*, Madrid, 1997; also an English translation of the text (without illustrations) is available as *Scientific instruments in the sixteenth century – The Spanish Court and the Louvain School*.

– , *A Catalogue raisonné of scientific instruments from the Louvain School, 1530 to 1600*, Turnhout, 2002

Gerard L'E. Turner, *Elizabethan instrument makers – The Origins of the London trade in precision instrument making*, Oxford, 2000 (the review in *Journal of the History of Collections* 15 (2003): 147-150 addresses novelty and innovation in Renaissance instrumentation)

– , *Renaissance astrolabes and their makers,* Aldershot & Burlington VT: Ashgate, 2003

Jim Bennett, "Mathematics and the Medici: Instruments and the Medici: Instruments from late Renaissance Florence and a British connection" (2008), at https://www.gresham.ac.uk/lectures-and-events/mathematics-and-the-medici-instruments-from-late-renaissance-florence-and-a (accessed 2017)

Note: There is also substantial literature on German and Italian instruments.

Important Festschrifts (for medieval instrumentation)

***Frankfurt IGN Festband*: Anton von Gotstedter, ed., *Ad radices – Festband zum fünfzigjährigen Bestehen des Instituts für Geschichte der Naturwissenschaften Frankfurt am Main*,** Stuttgart, 1994. Contains:

Silke Ackermann, "Mutabor: Die Umarbeitung eines mittelalterlichen Astrolabs im 17. Jahrhundert"
Richard Glasemann, "Zwei mittelalterliche französische Astrolabien"
Richard Lorch, "Mischastrolabien im arabisch-islamischen Kulturgebiet"
Kurt Maier, "Bemerkungen zu den romanischen Monatsnamen auf mittelalterlichen Astrolabien"
James E. Morrison, "Updating the astrolabe"
Petra Schmidl, "Ein Astrolab aus dem 17. Jahrhundert"

Burkhard Stautz, “Die früheste bekannte Formgebung des Astrolabs”
King, “Ein vergessenes Zahlensystem des mittelalterlichen Mönchtums” (as found on the Berselius astrolabe)

Kennedy Festschrift: King & George Saliba, eds., *From Deferent to Equant: Studies in the History of Science in the Ancient and Medieval Near East in Honor of E. S. Kennedy*, *Annals of the New York Academy of Sciences* 500 (1986)

Bernard R. Goldstein, “Descriptions of astronomical instruments in Hebrew”
Paul Kunitzsch, “Al-Khwârizmî as a source for the *Sententie astrolabii*”

Kunitzsch Festschrift: Menso Folkerts and Richard P. Lorch, eds., *Sic itur ad astra. Studien zur Geschichte der Mathematik und Naturwissenschaften. Festschrift für den Arabisten Paul Kunitzsch zum 70. Geburtstag*, Wiesbaden, 2000

- Elly Dekker, "A close look at two astrolabes and their star tables" (the medieval English lion astrolabe from Salzburg and the Great Sloane astrolabe);
- King, "The star-names on three 14th-century astrolabes from Spain, France and Italy";
- David Pingree, "A Greek list of astrolabe stars";
- Julio Samsó, "Maslama al-Majrîtî and the star table in the treatise de mensura astrolabii";
- Gerard Turner, "A critique of the use of the First point of arid in dating astrolabes"

Vernet Festschrift: Josep Casulleras and Julio Samsó, eds., *From Baghdad to Barcelona. Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet, 2 vols., Barcelona: Instituto "Millás Vallicrosa" de Historia de la Ciencia Árabe*, 1996. Contains:

- Paul Kunitzsch & Elly Dekker, "The Stars on the Rete of the So-Called "Carolingian Astrolabe"", in II, pp. 655-672
- David A. King & Kurt Maier, "The Medieval Catalan Astrolabe of the Society of Antiquaries, London", in II, pp. 673-718
- Sreeramula Rajeswara Sarma, "The Safîha Zarqâliyya in India", in II, pp. 719-735
- Roser Puig, "On the Eastern Sources of Ibn al-Zarqâlluh's Orthographic Projection", in II, pp. 737-753
- Emilia Calvo, "Ibn Bâso's Astrolabe [plate] in the Maghrib and East", in II, pp. 755-767

Juan Vernet, *Estudios sobre historia de la ciencia medieval*, Barcelona: Universidad de Barcelona (Facultad de Filología) & Bellaterra: Universidad Autónoma de Barcelona (Facultad de Filosofía y Letras), 1979

-- , *Estudios*, I-II: *idem*, *Estudios sobre historia de la ciencia medieval*, Barcelona: Universidad de Barcelona & Bellaterra: Universidad Autónoma de Barcelona, 1979, and *De 'Abd al-Rahmân I a Isabel II -- Recopilación de estudios dispersos ...* , Barcelona: Instituto "Millás Vallicrosa" de Historia de la Ciencia Árabe, 1989

Vernet, ed., *Estudios*, I-II: *idem*, ed., *Textos y estudios sobre astronomía española en el siglo XIII, and Nuevos estudios sobre astronomía española en el siglo de Alfonso X*, Barcelona: Universidad de Barcelona, 1981 and 1983

Vernet, ed., *Historia de la ciencia árabe*, Madrid: Real Academia de Ciencias Exactas, Fisicas y Naturales, 1981

Vernet, ed., *Textos y estudios*, A-B: *idem*, ed., *Textos y estudios sobre astronomía española en el siglo XIII*, and *Nuevos estudios sobre astronomía española en el siglo de Alfonso X*, Barcelona: Instituto de Filología, Institución "Milá y Fontanals", Consejo Superior de Investigaciones Científicas, 1981 and 1983

Detailed studies of individual astrolabes (selected)

Note: For a listing of the historically most significant astrolabes, inevitably subjective, see *Astrolabes and angels*, pp. 202-219

O. M. Dalton, "The Byzantine astrolabe at Brescia", *Proceedings of the British Academy* 12 (1926): 133-146 and 3 pls. See also *Astrolabes and angels*, pp. 27-31, 58, 71-72, 220-233 for additional information on this instrument

Burkhard Stautz, "Die früheste bekannte Formgebung der Astrolabien", in *Frankfurt IGN Festband*, pp. 315-328 (comparison of the 1062 Byzantine astrolabe and the 8th-century Baghdad one)

King, "The oldest known astrolabe, from 8th-century Baghdad", in *Synchrony*, XIIIb, pp. 403-438

– , "An instrument of mass calculation made by Nastûlus in Baghdad *ca*. 900", *Suhayl* 8 (2008): 93-119 (please stop calling him Bastûlus!)

– , "Two newly-rediscovered astrolabes from Abbasid Baghdad", *Suhayl* 11 (2012): 103-116

– , "An Ottoman astrolabe full of surprises", in Nathan Sidoli and Glen Van Brummelen, eds., *From Alexandria through Baghdad – Surveys and studies in Ancient Greek and Medieval Islamic mathematical sciences in honor of J. L. Berggren*, Heidelberg *etc*., 2014, pp. 329-345 (the surprise is a complete set of early Andalusî plates)

George Saliba, "A sixteenth-century drawing of an astrolabe made by Khafîf Ghulâm 'Alî b. 'Îsâ (c. 850 A.D.)", *Nuncius* 6 (1991):109-119

Bernhard Dorn, "Drei in der Kaiserlichen Öffentlichen Bibliothek zu St. Petersburg befindliche astronomische Instrumente mit arabischen Inschriften", *Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg*, VII[e] série, 9:1 (1865): 1-150 and 2 figs., repr. in *AIOS*, I, pp. 345-498

Vincenzo Mortillaro, "Illustrazione di un astrolabio arabo-sicula [sic]", Palermo, 1848, repr. in *AIOS*, I, pp. 162-191

Marcel Destombes, "Un astrolabe carolingien et l'origine de nos chiffres arabes", *Archives internationales d'Histoire des sciences* 58-59 (1962): 1-45 (see now ***Saragossa 1994 Conference Proceedings***)

Paul Kunitzsch & Elly Dekker, "The stars on the rete of the so-called "Carolingian Astrolabe"", in *Vernet Festschrift*, II, pp. 655-672

– , "Traces of a tenth-century Spanish-Arabic astrolabe", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 12 (1998): 113-120

Silke Ackermann, "Mutabor: Die Umarbeitung eines mittelalterlichen Astrolabs im 17. Jahrhundert", in von *Frankfurt IGBN Festband*, pp. 193-209

Petra G. Schmidl, "Knowledge in motion: An early European astrolabe and its possible medieval itinerary", *London 2014 Conference Proceedings = Medieval encounters* 23 (2017): 1-49

Jan P. Hogendijk, "A new look at the Barber's Astrolabe in the Arabian Nights", in A. Vrolijk & Jan P. Hogendijk, eds., *O ye Gentlemen: Arabic Studies on Science and Literary Culture in Honour of Remke Kruk*, Leiden, 2007, pp. 65-76

Frédéric Sarrus, "Description d'un astrolabe construit à Maroc en l'an 1208", *Mémoires de la Société d'histoire naturelle de Strasbourg* 4 (1853): 1-32, and pls. 1-6, repr. in *AIOS*, I, pp. 193-230

Franz Woepcke, "Über ein in der Königlichen Bibliothek zu Berlin befindliches arabisches Astrolabium", *Abhandlungen der Königlichen Akademie der Wissenschaften*, Berlin, 1858, 31 pp., repr. in *AIOS*

Kurt Maier, "Ein islamisches Astrolab aus Córdoba mit späteren altkatalanischen Inschriften", in Peter Eisenhardt, Frank Linhard and Kaisar Petanides, eds., *Der Weg der Wahrheit – Aufsätze zur Einheit der Wissenschaftsgeschichte – Festgabe zum 60. Geburtstag von Walter G. Saltzer*, Hildesheim, 1999, pp. 119-133

Bernard R. Goldstein, "The Hebrew Astrolabe in the Adler Planetarium", *Journal of Near Eastern Studies* 35 (1976), pp. 251-260, repr. in *idem*, *Theory and observation in Ancient and Medieval Astronomy*, London, 1985, XVIII

– & George Saliba, "A Hispano-Arabic Astrolabe with Hebrew Star Names", *Annali dell'Istituto e Museo di Storia della Scienza di Firenze* 8 (1983): 19-28, repr. in Goldstein, *Theory and observation ...* , XIX

King, "The medieval Yemeni astrolabe in the Metropolitan Museum of Art in New York", *Zeitschrift für Geschichte der arabisch-islamischen Wissenschaften* 2 (1985): 99-122, and 4 (1987/88): 268-269, with a new version "An Astrolabe made by the Yemeni Sultan al-Ashraf", in *Synchrony*, XIVa: 615-657

– , "The monumental Syrian astrolabe in the Maritime Museum, Istanbul", *Aydın Sayılı Özel Sayısı*, I-III, a special issue of *Erdem* (Ankara: Atatürk Kültür Merkezi), in three parts (9:25-27), Ankara, 1996-97, II, pp. 729-735 and 10 pls., repr. in *Synchrony*, XIVc

– & Kurt Maier, "The medieval Catalan astrolabe of the Society of Antiquaries, London", J. Casulleras & J. Samsó, eds., *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet*, 2 vols., Barcelona, 1996, vol. 2, pp. 673–718

– , "A remarkable Italian astrolabe from *ca*. 1300 – Witness to an ingenious Islamic tradition of non-standard astrolabes", in *MUSA MUSAEI: Studies on scientific instruments and collections in Honour of Mara Miniati*, Marco Beretta, Paolo Galluzzi and Carlo Triarico, eds., Florence, 2003, pp. 29-52, repr. in *Astrolabes from medieval Europe*, V; a new version is in *Synchrony*, XIIId: 545-574

– , "An astrolabe from Einbeck datable *ca*. 1330", in Joseph Dauben *et al*., eds., *Mathematics Celestial and Terrestrial – Festschrift für Menso Folkerts zum 65. Geburtstag*, *Acta Historica Leopoldina* 54 (2008): 161-178, repr. in *Astrolabes from Medieval Europe*, VI.

Burkhard Stautz, “Ein Astrolab aus dem Jahr 1420”, *NTM – Internationale Zeitschrift für Geschichte und Ethik der Naturwissenschaften, Technik und Medizin* (Basle: Birkhäuser), N.S., 5:3 (1997): 142-159

Rachel Ward, “The inscription on the astrolabe by ‘Abd al-Karîm in the British Museum”, *Muqarnas* 21 (2004): 345-358

John Davis, “Fit for a King: Decoding the Great Sloane Astrolabe and other English astrolabes with ‘quatrefoil’ retes”, in *Medieval encounters* 23 (2017): 311-354

— , “A Royal English medieval astrolabe made for use in Northern Italy”, *Journal for the history of astronomy* 48 (2017): 3-32

– & Michael Lowne, “An early English astrolabe at Gonville & Caius College, Cambridge, and Walter of Elveden’s *Kalendarium*”, *Journal for the History of Astronomy* 46 (2015): 257-290

King, “An astrolabe for the Sultan Ulugh Beg”, in *Synchrony*, XIVd: 745-774

– , “Rewriting history through instruments: The secrets of a medieval astrolabe from Picardy”, in Robert G. Anderson, James A. Bennett & Will F. Ryan, eds., *Making Instruments Count – Essays on Historical Scientific Instruments presented to Gerard L’Estrange Turner*, Aldershot (U.K.): Variorum, 1993, pp. 42-62, repr. in *Astrolabes from medieval Europe*, III

– , *The Ciphers of the monks – A forgotten number notation of the Middle Ages*, Stuttgart, 2001 (deals with the Berselius astrolabe with monastic ciphers as well as other 14th-century French astrolabes)

– , “An astrolabe from 14th-century Christian Spain with inscriptions in Latin, Hebrew and Arabic – A unique testimonial to an intercultural encounter”, *Suhayl* 3 (2002/03): 9-156, with a new version in *Synchrony*, XV: 831-914

– , “The astrolabe depicted in the intarsia of the *Studiolo* of Archduke Federico in Urbino”, in *La scienza del Ducato di Urbino – The Science of the Dukedom of Urbino*, Flavio Vetrano, ed., Urbino: Accademia Raffaello, 2001, pp. 101-139, also in *Astrolabes from Medieval Europe*, X

Mohamed Abuzayed, King and Petra G. Schmidl, “From a heavenly Arabic poem to an enigmatic Judaeo-Arabic astrolabe”, *Suhayl* 10 (2011): 85-142

Azucena Hernández (Pérez), “Astrolabes for the King: The astrolabe of Petrus Raimundi of Barcelona”, *London 2014 Conference Proceedings* = *Medieval encounters* 23 (2017): 421-443

– , "Arte y ciencia en al-Andalus: el astrolabio nazarí de Alcalá la Real”, *Boletín de Estudios Giennenses* 215 (2017): 259-284

Derek J. de Solla Price, “The first scientific instrument of the Renaissance”, *Physis – Rivista internazionale di storia della scienza* (Florence) 1 (1959): 26-30 (the first description of the 1462 Regiomontanus astrolabe)

King & Gerard L’E. Turner, “The Astrolabe presented by Regiomontanus to Cardinal Bessarion in 1462”, *Nuncius: Annali di Storia della scienza* (Florence) 9:1 (1994): 165-206, repr. in *Astrolabes from Medieval Europe*, XI

– , *Astrolabes and Angels, Epigrams and Enigmas – From Regiomontanus’ Acrostic for Cardinal Bessarion to Piero della Francesca’s Flagellation of Christ*, Stuttgart, 2007, with CD-ROM (deals with the Regiomontanus astrolabe of 1462 and its relationship to the 1062 Byzantine astrolabe)

Sreeramula Rajeswara Sarma, "A monumental astrolabe made for Shâh Jahân and later reworked with Sanskrit legends", *London 2014 Conference Proceedings = Medieval encounters* 23 (2017): 198-262

William H. Morley, *Description of a Planispheric Astrolabe constructed for Sháh Sultán Husain Safawí ...* , London, 1856, repr. as the introduction to Gunther, *Astrolabes of the World*, I, and again in *AIOS*, I, 249-325; also *idem*, "Description of an Arabic quadrant", *Journal of the Royal Asiatic Society* 17 (1860): 322-330 and two figs., repr. in *AIOS*, I, pp. 326-336

Anonymous, "An important single sheet European universal astrolabe, not signed or dated, ... 15th century", at https://www.bonhams.com/auctions/21933/lot/189/

Petra Schmidl, "Ein Astrolab aus dem 17. Jahrhundert – prachtvoll und verfälscht", in *Frankfurt IGN Festband*, pp. 291-314

Peggy Alrich Kidwell, "The Astrolabe for latitude 41°N of Simeon de Witt: An early American celestial planisphere", *Imago mundi* 61 (2009): 91–96

Other relevant works

Richard P. Lorch, "Some early applications of the sine quadrant", *Suhayl* 1 (2000): 251-272

J. Lennart Berggren, "Medieval Islamic methods for drawing azimuth circles on the astrolabe", *Centaurus* 34 (1991): 309–344

King, "On the origin of the astrolabe according to the medieval Islamic sources" (1981), with a new version in *Synchrony*, XIIIe: 575-611

Donald R. Hill, "Al-Bîrûnî's mechanical calendar", *Annals of science* 42 (1985): 139-163, repr. in *idem*, *Studies in Medieval Islamic Technology: From Philo to al-Jazarî – from Alexandria to Diyâr Bakr*, Aldershot & Brookfield VT: Ashgate-Variorum, 1998, XIV

Owen J. Gingerich, "Zoomorphic astrolabes and the introduction of Arabic star names into Europe", in *Kennedy Festschrift*, pp. 9-104

– & King & George Saliba, "The 'Abd al-A'imma astrolabe forgeries", *Journal for the history of astronomy* 3 (1972): 188-198, repr. in King, *Islamic astronomical instruments*, VI

Silke Ackermann, "Astrological scales on the National Maritime Museum astrolabes", in *Astrolabes at Greenwich*, pp. 73–89

King, *World-Maps for finding the direction and distance to Mecca*, Leiden & London, 1999 (includes much information on 17th-century Iranian astrolabes, especially on the geographical tables with qibla values on their maters)

– , "On shadow scales", in *Synchrony*, XIIa: 247-255

– , "On the universal horary quadrant for timekeeping by the sun", in *Synchrony*, XIIa: 199-336

– , "Quatrefoil decoration on astrolabe retes", in *Synchrony*, XVII: 963-992

Paul Kunitzsch, *Typen von Sternverzeichnissen in astronomischen Handschriften des zehnten bis vierzehnten Jahrhunderts*, Wiesbaden, 1966

– , ***The Arabs and the Stars***, Northampton: Variorum, 1989. Contains *inter alia*: I: "Medieval Star Catalogues", IV: "Two star tables from Muslim Spain", VII: "Arabic Reception of the astrolabe", VIII: "The Terminology of the Astrolabe", IX: "Al-Khwârizmî as a source for the *Sententie astrolabii*", X: "Messahalla on the astrolabe", XXI: "John of London and his unknown Arabic source"

Fer J. de Vries, "Some notes on the use of an astrolabe" (2009), at downloadable from www.nicolaseverino.it/

Kurt Maier, "Bemerkungen zu romanischen Monatsnamen auf mittelalterlichen Astrolabien", in *Frankfurt IGN Festband*, pp. 237-254, and *idem* , "Zeugen des Mehrsprachigkeit: mittelalterliche romanische Monatsnamen auf islamischen astronomischen Instrumenten", in Jens Lüdtke, ed., *Romania arabica. Festschrift für Reinhold Kontzi zum 70. Geburtstag*, Tübingen, 1996, pp. 251-270

Baxter D. Wilson, "The astrolabe and medieval English life", *Popular astronomy* 57 (1947): 155-169, accessible through http://adsbit.harvard.edu/ (no hype)

Nicola Severino, *Il libro degli astrolabi – La storia dell'astrolabio da Tolemeo a Regiomontano*, Roccasecca, 1994 {apparently written without looking at a single actual astrolabe}

Astrolabes in works of art and works of art inspired by astrolabes (selected)

Koenraad van Cleempoel, "Representation of astrolabes in Western art", in *Greenwich Catalogue*, pp. 99-111

Jonathan K. Nelson, "L'astrologo e il suo astrolabio: l'*Adorazione dei Magi* di Filippino Lippi del 1496", in Eike Schmidt & Marco Ciatti & Cecilia Frosinini, eds., *Il cosmo magico di Leonardo da Vinci nell'*Adorazione dei Magi *restaurata*, Florence: Gallerie degli Uffizi, 2017, pp. 74-91

John D. North, *The Ambassadors' secret – Holbein and the world of the Renaissance*, London: Hambledon & London, 2002

King, *Synchrony*, XIIId: 572-574 (Detroit Jan van Eyck)

King, "The astrolabe depicted in the intarsia of the *Studiolo* of Archduke Federico in Urbino", in *Astrolabes from Medieval Europe*, X

Azucena Hernández, "El Tapiz del Astrolabio o la sutil infiltración de lo divino en una visión cosmográfica bajomedieval", in Gerardo Boto, ed., *Lo profano en el arte sagrado medieval,* Aguilar de Campoo (Palencia), Fundación Santa María la Real del Patrimonio Histórico (in press)

King, *Astrolabes and Angels* (Regiomontanus' 1462 astrolabe and Piero della Francesca's *Flagellation of Christ*)

5th VERSION
17 January 2018

Acknowledgements

It is a pleasure to acknowledge my debt to Shefayet Chowdhury for help in obtaining relevant literature. Various colleagues made helpful suggestions to improve drafts of this paper, none of whom should be held responsible for what it now contains. So my thanks to John Davis, Azucena Hernández Pérez, Raja Sarma, Hüseyin Sen, Raya Wolfsun, •••••••• ••**MENTION ANYONE ELSE WHO COMMENTS ON THIS VERSION**•.

The author

David A. King (b. 1941) is a British-born orientalist and historian of astronomy. He studied at Cambridge (Maths), Oxford (Education), and Yale (Near Eastern Languages & Literatures). His first appointment was with the Sudan Government Ministry of Education (1964-67), and later he directed a project in the history of medieval Islamic astronomy sponsored by the Smithsonian Institution and based at the American Research Center in Egypt (72-79). He has been Professor of Near Eastern Languages & Literatures at New York University (79-85) and thereafter Professor of the History of Science at the J. W. Goethe University in Frankfurt.

King has researched thousands of Arabic scientific manuscripts and hundreds of medieval astronomical instruments in libraries and museums around the world. His *World-Maps for finding the direction and distance to Mecca* (1999) and other writings on the qibla and the sacred geography of Islam have surveyed the ways in which Muslims for well over a millennium have determined the sacred direction towards the astronomically-oriented Kaaba in Mecca. This research explains the often curious orientations of medieval mosques. His *magnum opus* entitled *In Synchrony with the Heavens* (2004/05) contains the first description of the ways in which Muslims have regulated the astronomically-defined times of the five daily prayers for well over a millennium. A second volume deals with the instruments that Muslim astronomers used. His first regional study – astronomy in medieval Yemen – was published in 1983. His last – astronomy in medieval Jerusalem – was published in 2018. Many of his publications on the history of astronomy in Islamic civilization can be downloaded from davidaking.academia.edu.